

PULSE-GAUGING

G. OLIVER, M.D.

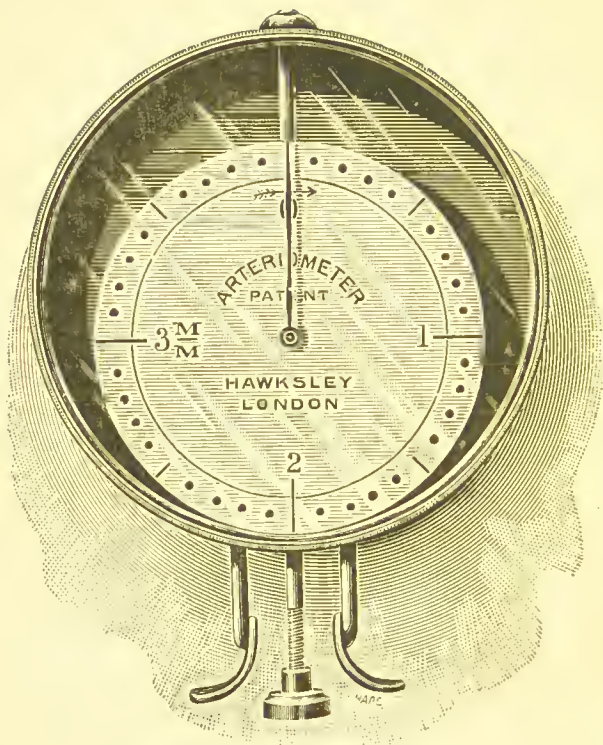


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✓
Dr Mitchell Bruce

With the writer's
best regard.

PULSE-GAUGING



THE ARTERIOMETER.

PULSE-GAUGING

A CLINICAL STUDY OF RADIAL MEASUREMENT
AND PULSE-PRESSURE

BY

GEORGE OLIVER, M.D. LOND., F.R.C.P.

AUTHOR OF "BED-SIDE URINE TESTING"
"THE HARROGATE WATERS," ETC.

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TO

J. RUSSELL REYNOLDS,

M.D. Lond., F.R.S.

PRESIDENT OF THE ROYAL COLLEGE OF PHYSICIANS
OF LONDON, ETC.,

WHOSE TEACHING, FRIENDSHIP, AND VALUED COUNSEL

HAVE LARGELY CONTRIBUTED TO MY

SUCCESS AND HAPPINESS,

I DEDICATE THIS LITTLE VOLUME

WITH SINCERE REGARD.



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PREFACE.

IN the following pages I have endeavoured to present an outline of the principal results obtained by the application of the methods of observation of the pulse, which I have followed during the past three or four years. The data thus yielded have afforded me such practical clinical guidance, that I am fain to think there are some who may care to put them on trial, and who may find this chart somewhat useful in their attempts to study the pulse on the lines which I have adopted.

In the earlier years of my practice I patiently applied the sphygmograph; but I eventually concluded that the clinical aid which it can provide is but limited, and by no means commensurate with the

time and trouble which the application of that instrument demands. As years went on I could not divest myself of the impression that some other instrumental mode of observation of the pulse would eventually be discovered, which would amplify and render more definite all the practical aspects of pulse-feeling: and, when some few years ago, I secured the freedom and leisure of the winter months I ventured to attack this problem. Since then my practice at Harrogate, and the various opportunities for observation which my friends have afforded me in the London hospitals, have enabled me to test the practical capabilities of the methods of observation I had devised.

Guided solely by observation, I have been led to follow a path which has yielded results of some promise; and I confess I should now find myself at a considerable clinical disadvantage were I to lay aside my arteriometer and pulse-pressure gauge. Though these instruments have contri-

buted considerably to the training of the finger (which must always retain the primary place in pulse exploration), they still remain to me indispensable ; for they provide a clear definition of the tactile impressions, which cannot otherwise be recorded with any approach to exactitude.

My field of work at Harrogate is peculiarly favourable to the application of the methods of observation I have adopted,* and this circumstance has largely incited me to the prosecution of this enquiry.

A clinical study such as this has many ramifications and connections. I have merely touched on those that have fallen within the range of my own experience, and there necessarily remains much to be

* A large proportion of my cases are chronic, and, inasmuch as many of them appear year by year, or at intervals of a year or two, I find the recording of the facts gleaned by the pulse-instruments of considerable value, in enabling me, with other data, to note changes in the individual, which are of pathological and clinical interest.

settled and explained by more extended observation.

I am under much indebtedness to many friends—too numerous to be mentioned individually—for their generous aid in affording me opportunities of making observations, and in giving me valuable suggestions; and my best thanks are due to the Editors of the *Practitioner* for their permission to use several blocks of figures which were employed to illustrate my paper on “Pulse-Pressure.”

The substance of Chapter II., Part I., was read as a paper at the Meeting of the Physiological Society, held at King's College in February last.

Of late years medical literature has grown so extensive, that I think it is incumbent on writers to express themselves as tersely as possible. I have, therefore, endeavoured to follow this injunction.

HARROGATE: *November, 1894.*

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PART I.

RADIAL MEASUREMENT.

CHAPTER I.

THE MODE OF OBSERVATION.

1. *The Principle of the Writer's Arteriometer.*

THE internal diameter of a rubber-tube, placed upon a resisting surface, may be determined from the outside by a suitable mechanical arrangement. For example, let (1) two foot-rests be planted by the sides of the tube; and (2) let a pad, connected with an indicator on a dial, settle on it—when its position, as the starting point of the measurement, will be shown; and (3) let the pad be pushed forward so

as to close the bore—when the space thus traversed will be recorded by the indicator (fig. 1).

This principle is followed in determining the calibre of the radial or temporal artery by the arteriometer; the reading being taken when the pulsation ceases beyond

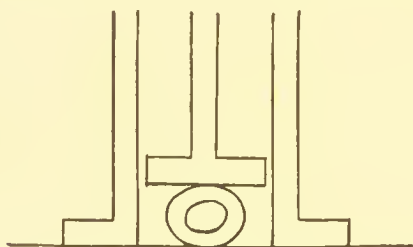


FIG. 1.—Diagram showing the principle of the writer's arteriometer.

the pad—the bore of the artery then being closed.

2. *The Arteriometer.*

THE mechanism is enclosed in a small circular box; faced by a dial, graduated in four millimètres (each mm. being divided into tenths); and presenting below three stems, carrying the foot-rests and

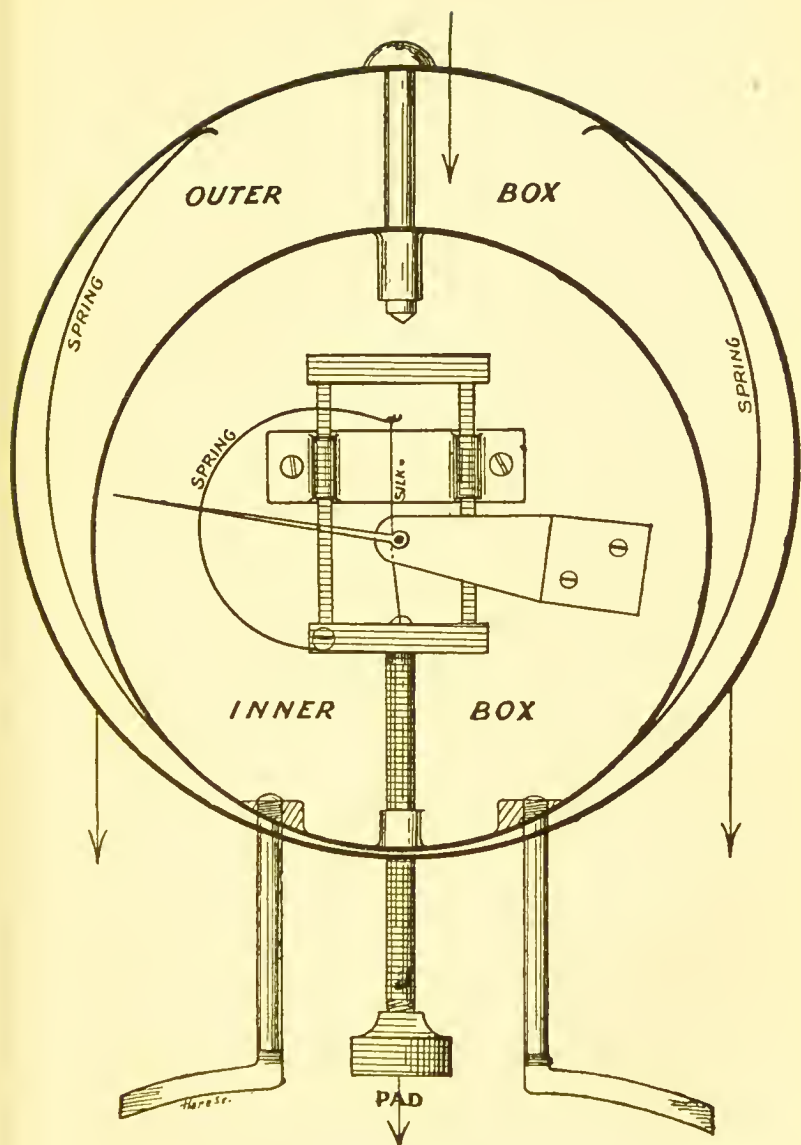


FIG. 2.—Section of arteriometer.

the pad. The sectional drawing (fig. 2) shows the details of construction. The stem to which the pad is screwed, is free to settle over the site of the artery; and attached to it is a silk thread, which is maintained in a state of uniform tension around the axle by a piece of hair-spring, and communicates to the hand on the dial the exact position of the pad. A rod comes down on this stem, when the forward movement is made to close the artery. The instrument is enclosed in an outer case; and when it is applied, the latter—carrying the rod just referred to—is merely pressed over it through the intervention of springs placed between them. This arrangement secures uniformity of pressure on the foot-rests throughout every observation. It will be observed, that the force used to effect the closure of the artery is that of the hand exerted through the travelling rod; this force being always in excess of the blood-pressure, otherwise the indicator would not travel on the dial.*

* The instrument was made for me by Mr. Hawkesley, Surgical Instrument Maker, 357 Oxford Street, W.

3. *How to apply the Arteriometer.*

OF the superficial arteries the radial is best adapted to the purpose in view ; for, the calibre of it is sufficiently large to provide an ample scale for the definite recording of variations ; and, moreover, the vessel occupies an accessible position on a bony floor, and is flanked by firm structures. The temporal artery is somewhat too small for general selection ; though the measurement of its calibre may now and then prove useful, when the radial arteries are not available for trustworthy observation.

Two conditions must be observed in order to make the reading as reliable as possible :—(1) The wrist must always be extended at a uniform angle ; and (2) the same part of the artery must be observed on all occasions. The first condition is secured by placing the extended arm on a wrist-rest providing an angle of 45° ;

* This angle of extension generally secures a slight and uniform traction of the tissues, which favours de-

and the second, by marking with an aniline pencil the site of that portion of the artery selected for measurement. A preliminary examination by the finger quickly enables the observer to decide, where the bed of the artery is most even and resistant, and therefore best adapted to the observation; and, as a rule, this is found to be on a level with the prominent point of the styloid process.

Figure 3 represents the most convenient way of applying the arteriometer. The instrument is held by the index finger and thumb of the right hand; the foot-rests are planted, one on the styloid process, and the other on the flexor tendons rendered firm by the extension just referred to; and the pad is made to occupy the exact site of the artery. The index finger of the left hand is placed over the artery beyond the pad; and the outer case is drawn slowly downwards. At first the indicator travels until it reaches a certain

finite observation; for example, the tendon of the flexor carpi radialis thus becomes a resistant platform for one of the foot-rests.

point, when it turns in the opposite direc-

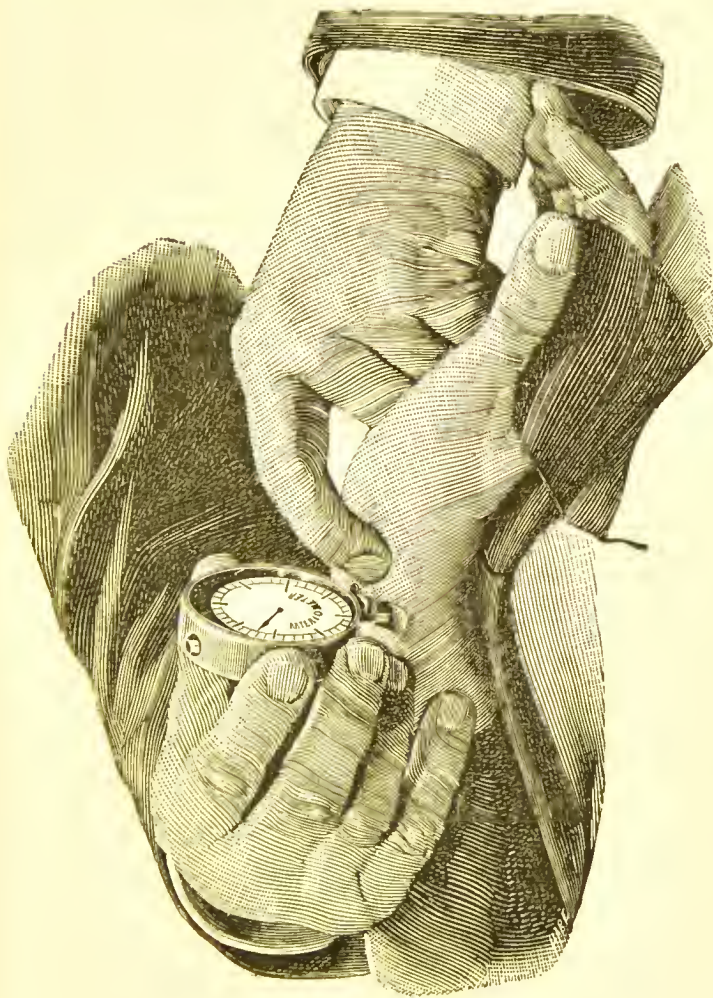


FIG. 3.—The mode of applying the arteriometer.

tion ; this point should be carefully noted, for then the pad begins to close the artery, and the reading of the measurement should commence. As the artery is being closed, the pulsation felt by the index finger after a time gradually diminishes, until it fails to be perceived, when the observation is at an end, and the travel of the indicator will furnish the measure of the calibre.* It is generally necessary to raise slightly the radial side of the wrist, in order to secure a firm and even base on which to compress the artery.

* According to my observation, the finger is the best and most practical guide in deciding when pulsation ceases, and the artery is closed ; it is, moreover, endowed with a surprising degree of sensitiveness, *e.g.*, on applying the arteriometer to determine the bore of a small rubber tube, through which water was intermittently propelled under a pressure resembling that within the arteries of man—as indicated by an attached mercurial manometer—the left index finger could definitely detect pulsation beyond the pad, until the pulsatile movement of the mercury and the flow of water actually ceased. I am disposed to think, that the left index finger is more sensitive than the right : perhaps because the epidermis on that side is slightly thinner—the more frequent use of the right hand tending to thicken it.

4. *Sources of Fallacy.*

THERE must always be a certain proportion of cases unsuited to any reliable instrumental observation of the radial artery; as when the vessel is abnormally distributed, or lies too deep, or when there is an excessive deposit of fat over it. Perhaps, however, not more than 10 or 15 per cent. of cases should be thus excluded. The instances, in which the radius provides an insufficient support for compression of the artery, in consequence of shelving away too rapidly, are totally unfitted; but the finger can, as a rule, readily detect such cases. The fulness of any superficial veins over the site of the artery might increase the reading; but this source of error is easily removed by making slight traction on the skin before adjusting the pad. A congested state of the tissues—as from heat or exercise—adds slightly to the measurement: hence I regard the reduction of the calibre observed in the second stage of exercise, and as the result of hot baths

(see pp. 15, 20, 21) to be understated rather than otherwise. But under ordinary circumstances, my observations have shown, that the compressibility of the tissues over the artery, and between it and the bone, do not increase the reading to any large extent; for, whereas the average measurement of a large number of maximum calibres was 2.2 mm., that of the excised radials I have determined was very nearly 2 mm.; and it will be remembered, that the withdrawal of the blood-pressure after death allows the external tension of the arterial wall to come into play, and the bore of the vessel is thus diminished.

There must of course always be a modicum of error; and, doubtless, the increased compressibility of the loose tissues to be met with in certain exceptional cases, will considerably exaggerate the measurement—as an absolute one.

But I am disposed to think, that, after excluding obviously unsuitable cases, this mode of observation provides a fair and practical approximation to accuracy and reliability; and that any objection to it

founded on anatomical considerations will scarcely apply, when it is borne in mind, that the leading fact, which I seek to record, is the variation (if any) of the calibre caused by change of posture—for any structural source of fallacy that may exist, will be common to the postures, and should not disturb the relative value of the observations made in each case.

CHAPTER II.

THE CALIBRE OF THE ARTERIES IN HEALTH: PHYSIOLOGICAL VARIATIONS.

1. *The calibre of the Arteries in health is always varying within certain limits.*

To the unaided finger the superficial arteries, in health as well as in disease, afford the impression of a certain degree of variability in calibre. This tactile sensation of enlargement or diminution is, however, somewhat vague, and is largely affected by the force and character of the pulsations; but it may be resolved by the arteriometer into something definite and capable of being recorded. Extended observation with this instrument has revealed the fact, that the arteries are constantly fluctuating in calibre; the variations following a definite order in response to change of posture, and of other physiological conditions.

The range of normal variation of the radial calibre is very considerable; as a rule, it is rarely less than 25 per cent. above or below a certain mean—for instance, an average calibre of 2 mm. may rise to 2.5 mm., or may fall to 1.5 mm. But in exceptional conditions, it may exceed these limits by several points.

2. *The Calibre in the Postures** (recumbency, sitting and standing).

A CHANGE of posture is almost invariably accompanied by an immediate alteration in the calibre. The variation thus induced follows, as a rule, one of two directions: either falling or rising as recumbency is assumed; and in either case it is rarely less than from 0.4 to 0.6 mm. On rare occasions, however, postural variations can-

* In recumbency the muscles should be relaxed, and the legs should be in a line with the body; in the sitting posture the back should not be supported; and in all the postures the position of the wrist should not exceed about two inches below the level of the heart's apex.

not be detected, but, as a rule, in health such an observation depends on quite transitory conditions. The first form of variation, characterized by the minimum calibre as it is found in recumbency, is that which is commonly followed in vigorous subjects of both sexes; and the second, in which the recumbent is the maximum calibre, is apparent for variable periods during the digestion of a full meal, after a certain amount of muscular effort, and generally when the body is tired as the result of labour and exercise, or is below par (see p. 32).

As a rule, as years advance beyond the middle period of life, the range of postural variation becomes gradually lessened, and it may thus mark the progress of physiological arterio-sclerosis, until the calibre may at last become quite uniform in posture (see p. 36). The period when restricted variation may set in is apparently a pretty wide one; for, it seems to me to embrace from about the 55th to the 70th or the 75th year. I have, moreover, met with several examples of remarkable play of the arterial wall in posture in persons

of between 75 and 80 years of age, whose bodily and mental vigour was unusually well preserved.

3. *The Calibre in Movement and Exercise.*

MUSCULAR action immediately increases the radial calibre. This fact may be shown in a small way by adjusting the instrument over one's left radial artery, and merely keeping it absolutely steady by the careful adaptation of the fingers over the foot-rests; when, after sitting at ease with the back supported, on rising in the chair to an erect sitting posture, the indicator may rise 0·1 mm.; and, on standing, may advance another point; and on walking across the room, may further ascend a point or two. Active exercise at first enlarges the radial calibre in all the postures, and then diminishes it in sitting and standing—when the maximum measurement becomes apparent in recumbency. I have observed, that the reduction in the active postures is associated with muscular effort, as in climbing;

and disappears with rest, or may become greatly modified on attaining level or descending ground, for example:—

		RADIAL CALIBRE IN MM.	
		SITTING.	RECUMBENT.
Before exercise . . .		2·0	1·5
Up-hill (steep) 500 ft.	{ In 15 mins.	2·2	1·6
	{ " 30 "	1·9	1·8
	{ " 45 "	1·6	2·0
Level	{ " 60 "	1·8	2·0
	{ " 75 "	1·6	1·6
Down hill	{ " 120 "	1·9	1·8

On the other hand, an artery like the temporal, which is not supplied to muscles actively employed in exercise, becomes much distended by continuous muscular effort, and is not reduced*; and the radial

* That the temporal arteries do become much distended by continuous muscular effort, is shown by the observations of Dr. N. (Prof. Oertel's patient), who measured by calipers the enlargement which took place in them during his climbing efforts. It extended from

on the side on which the arm is slung at rest likewise enlarges, while the corresponding vessel in the arm freely exercised diminishes.

	RADIAL CALIBRE IN MM. STANDING.	
	RIGHT.	LEFT.
Before ascending steep hill } 600 ft. }	2.2	2.2
{ <i>Right arm slung at rest.</i> }		
{ <i>Left arm in action.</i> }		
In 40 minutes	2.4	1.8
{ <i>Right arm in action.</i> }		
{ <i>Left arm slung at rest.</i> }		
In 20 minutes	1.9	2.2
<i>Both arms in action.</i>		
In 30 minutes	1.9	1.9

This observation may go far to explain the freshening and tonic effects of exercise on the brain—the cerebral vessels receive

mere visibility to a maximum rise of 2 mm. and a width of 3 mm. See *Therapeutics of Circulatory Derangements*, by Prof. M. J. Oertel, M.D., translated by E. J. Edwards, M.D., (1887).

ing an increased charge of blood throughout.*

The forms of massage denominated effleurage, pétrissage, and tapotement, when applied to the muscles of the forearm, produce quite different effects on the radial calibre: pétrissage, which compresses and empties the capillaries, reduces it; while effleurage and tapotement, which merely stimulate the vessels, increase it. For example:—

CASE I.		CASE II.	
	mm.		mm.
Commencing calibre .	1·7	Commencing calibre .	1·8
Pétrissage 5 min . .	1·4	Effleurage 5 min. . .	2·1
" " . .	1·4	Pétrissage " . .	1·7
Effleurage " . .	1·7	" " . .	1·5
" " . .	1·8	Tapotement 3 min. .	1·8

4. *The Calibre during Digestion.*

REPEATED observation has shown, that during the digestion of a full meal (*e.g.*, dinner in the evening), the measurement of the radial calibre shows—

* The brain-clearing, and indeed the brain-nourishing, effects of the judicious use of exercise and out-of-door games has undoubtedly a firm physiological basis.

(a) *Reduction in the sitting posture*, which begins in from fifteen to thirty minutes after the conclusion of the meal, and attains its maximum fall from thirty to sixty minutes: and (b) *expansion in recumbency*. In about an hour and a half the calibres in both postures may exceed those observed before the meal began.

Example:

	RADIAL CALIBRE IN MM.	
	SITTING.	RECUMBENT.
Before dinner	2.0	1.5
15 min. after dinner . . .	1.8	1.6
30 " " " " . . .	1.8	2.3
45 " " " " . . .	1.7	2.6
60 " " " " . . .	1.6	2.3
75 " " " " . . .	1.9	2.3
90 " " " " . . .	1.8	2.2
105 " " " " . . .	2.3	1.8

5. *The effects of External Temperature on the Calibre of the Arteries.*

It is well known that the calibre of the arteries is very readily affected by variations of external temperature.

In order to determine the effect of temperatures, ranging from 40° to 120° F. on the radial calibre, I immersed the forearm in water for the definite period of three minutes at each observation, and, on the removal of the arm, I immediately measured the calibre in a uniform atmospheric temperature of 60° F. The following table provides a summary of these observations.

IMMERSION IN TEMP. F.		R. CALIBRE IMMEDIATELY AFTER IMMERSION.
R. calibre 2.2 mm. before each immersion.	40°	1.3 mm.
	50°	1.4 "
	60°	1.5 "
	70°	1.7 "
	80°	2.0 "
	90°	2.2 "
	95°	2.2 "
	96°	2.2 "
	97°	2.3 "
	98°	2.4 "
	100°	2.6 "
	101°	2.5 "
	102°	2.4 "
	103°	2.2 "
	104°	2.1 "
	105°	2.0 "
	110°	1.7 "
	115°	1.6 "
	120°	1.5 "

It will be observed, that the immersions

in the temperatures from 90° to 96° did not disturb the calibre: those in 97° to 99° enlarged it— 99° and 100° inducing the maximum enlargement: those in 101° and 102° still enlarged it, but to a small extent: that in 103° did not produce a discoverable effect: and those in higher temperatures reduced the calibre in proportion to the rise of temperature. Below 90° the calibre also fell—*pari passu* with the reduction of temperature.

Hot baths (from 100° to 105°) quickly reduce the radial calibre: and warm baths (from 97° to 100°) enlarge it—though, when the temperature is maintained for a certain time at 99° or 100° , reduction, as a rule, takes place.

A reduction is likewise effected by the Turkish bath, for example:—

	SITTING.	RECUMBENT.
R. calibre before bath . .	2.5 mm.	2.1 mm.
After 20 min. 250° . . .	2.0 „	1.5 „
„ 15 „ „ . . .	1.6 „	2.0 „
„ cold shower . . .	2.0 „	1.6 „

The radial calibre is also lessened by the application of heat to a distant part. For instance, I have observed, that immersion of the feet in hot water for twenty minutes, the high temperature being well maintained the while, may reduce a radial calibre of 2.2 mm. to 1.3 mm.; and, on allowing the water to cool, it may gradually rise to 1.8 mm. or so. I have also found, that on immersing an arm in hot water (115° F.) the calibre of the radial artery on the opposite side may fall from 2.0 mm. to 1.6 mm.

6. The Calibre in relation to Mechanical Causes affecting the Distribution of Blood.

GRAVITY affects the radial calibre slightly; for, I find the measurement varies somewhat when the wrist is placed at different levels in relation to the heart. For example, the subject being recumbent, a calibre of 1.6 mm. at the level of the heart may become 1.7 mm. ten inches below, and 1.4 mm. 10 inches above that level.

Raising the legs passively increases the radial calibre. A measurement of 1·7 mm. in recumbency may, on putting both legs up and supporting them, advance in two minutes to 2·2 mm., and, on lowering them, may return in three minutes to 1·7 mm.

I have observed, that on reducing the atmospheric pressure on one leg by the application of Junod's boot, the radial calibre of 1·8 mm. may fall to 1·2 mm., and, on allowing the air to re-enter the boot, the original measurement may be restored in ten minutes.

It, therefore, seems possible to control the circulation of a certain quantity of blood by mere mechanical means.

7. The relation between the Calibre of the Arteries and the Surface Temperature.

I HAVE observed, that the temperature (sublingual)* varies in direct proportion

* Though axillary temperatures provide readings, which correspond, as a rule, with sublingual ones, they are upon the whole less trustworthy.

to the diameter of the radial artery as determined by the arteriometer. According to the observations I have hitherto made, the extreme variations of temperature, recorded in the different physiological conditions of the same individual, are confined within comparatively narrow limits—from 1.0° to 1.5° F.; but, as a rule, they have maintained a pretty constant relation to the size of the radial—as when from any cause, the variations of the radial calibre, induced by posture, digestion, or exercise, became more restricted, or more ample than usual, the temperature followed suit *pari passu*.

I am satisfied as to the correctness of this position in regard to posture;* I cannot, however, speak so assuredly of this

* Since making out this fact, I find that Kernig (quoted by Wunderlich) and Liebermeister (quoted by Prof. Bouchard) had already demonstrated on healthy men, that the axillary temperature is a few tenths of a centigrade degree lower in recumbency than in the sitting and standing postures: and Prof. Bouchard confirms this position—his observations having been made on the rectal temperature. *British Medical Journal*, April 14th, 1894.

relationship in the other physiological conditions which affect the calibre, because my data are as yet insufficient. The following average example illustrates this interesting connexion in posture.

	RADIAL CALIBRE IN MM.	SUBLINGUAL TEMP.
Recumbent . . .	1.5	98.0° F.
Sitting	1.9	98.5° F.
Standing . . .	2.5	98.9° F.

8. *The probable causes of Variation of the Calibre.*

1. DIMINUTION of the radial calibre may arise from :—

(a) *Contraction of the arterial wall* : as from cold and from high temperature. Possibly the artery is reduced by contraction in the active postures during the second stage of exercise, during digestion (perhaps as a reflex effect), and whenever the maximum calibre appears in the passive posture.

(b) *Passive reduction* : as from lowering

of the heart's action—hence, perhaps, the minimum calibre in recumbency; or from relaxation of the small arteries favouring the flow into and through the periphery—as from excessive or continued heat, or exercise.

2. ENLARGEMENT of the radial calibre may result from :—

(a) *Reduced arterial tone* : as from moderate heat.

(b) *Distension* : as from increase of the heart's action—*e.g.*, in the active postures, and in the first stage of exercise; or from peripheric obstruction, such as constriction of the small arteries—as when the calibre enlarges in the passive posture, as the result of effort, fatigue, digestion, &c. The cause of this enlargement does not at first sight seem very obvious; but I think it is not improbable, that it may be ascribed to a limitation to the terminal arteries of the widely diffused contraction which reduces the radial calibre in the sitting posture. I have observed in experiments on animals, that, when the arteries distributed to the limbs and to the viscera

are thrown into energetic contraction by the intra-venous injection of supra-renal extract (see ch. iv., 3), the central arteries—such as the carotid—become greatly distended and enlarged; the contraction of all the arteries below a certain size raising the blood-pressure, which dilates the large vessels. It is but reasonable to suppose, that were the contraction to be limited to the small arteries only, the consequent rise of blood-pressure will expand all the arteries of larger size. It is, therefore, not improbable, that in the physiological conditions just referred to, the arteries (including those of moderate size like the radial) are in the sitting posture contracted, and thus reduced in calibre; and, that in recumbency, the radial enlarges, because the constriction ceases to affect it, and becomes confined to the vessels of smaller size only, where by increasing the peripheral resistance it augments the blood-pressure, and thus distends the arteries between it and the heart.*

* When the radial calibre falls on changing the posture from sitting to recumbency, in all probability the

This condition of the arterial wall in posture may be reflected from some distant source of irritation or discomfort. Thus I have repeatedly observed, that it exists whenever there is a call to stool; and the normal arrangement of the radial calibres is restored at once by the evacuation. This physiological fact of reflected arterial contraction has some pathological bearing (see pp. 32, 33, 42-49).

What relation (if any) subsists between the calibre and the frequency of the heart's action and the blood-pressure? Though I have made a large number of observations in which the pulse-rate* was carefully recorded by the side of the measurements of the radial calibre, I have failed to discover any definite relation (direct or indirect) between the two. It may be said, surely as the frequency has a recognizable connexion with the postures, it may be similarly related to the calibre also. If

arterial tonus diminishes pretty equably throughout—the peripheral on-flow being thus favoured.

* This was invariably taken by counting for the whole minute.

that were so, the pulse-rate should rise in recumbency when the calibre is found to be the largest in that posture. But it does not do so; for, on taking 50 consecutive observations in which the recumbent calibre exceeds that of sitting, and 50 consecutive observations in which it follows the reverse order, I find the relative average frequency between the two postures is the same in both classes.

	RECUMBENT CALIBRE.	PULSE-RATE.	
		SITTING.	RECUMBENT.
50 observations .	maximum	69·8	63·5
50 observations .	minimum	69·7	63·5

Individual observations, made in quite different physiological conditions, might likewise be quoted to strikingly disprove any connexion between the pulse-rate and the calibre.

I have made a pretty large number of observations with my pulse-pressure gauge (see Pt. II., ch. i.) with the view of ascer-

taining if any relation subsists in health between the blood-pressure and the radial calibre ; but I find recorded a good many apparent exceptions to any general rule that may be formulated. I am, however, inclined to think, that under physiological conditions there is a general direct connexion between them, which in the pathological field is apt to be considerably disturbed (see p. 53).

CHAPTER III.

THE CALIBRE OF THE ARTERIES IN DISEASE : PATHOLOGICAL VARIATIONS.

I. *The Pathological Variations are Determined by the Physiological.*

IN the pathological field the physiological variations of the radial calibre are apt to become disturbed in a marked degree ; and they naturally form the standard, by which the clinically observed departures are to be gauged. I have found the effects of posture on the radial calibre to form the most convenient practical test, in order to determine the pathological deviations ; and for this purpose, it is in the majority of cases sufficient to apply the arteriometer merely in the sitting and recumbent postures. But in certain cases I have observed, that the calibration of the artery in the standing posture may likewise yield useful information (see p. 63).

The application of this test has shown, that in clinical observation the leading departures from the average physiological variation of the radial calibre consist of the much greater prevalence of:—

(a) The maximum measurement in recumbency.

(b) The absence of postural variation.

(c) A restricted or more ample range of postural deviation.

2. *The Maximum Calibre in the Recumbent Posture.*

I HAVE already pointed out the leading conditions in health, in which I have observed the radial calibre to be larger in recumbency than in the sitting posture; and, that when this arrangement obtains, it quickly passes away, and is indeed always temporary.

But in the clinical field, I have often found it to be less or more permanent in certain cases: cases in which the prominent pathological features were due to asthenia, or to some form of irritation, or

more commonly to a combination of both of these conditions.

In the asthenic group were included anæmia, cardiac asthenia, neurasthenia, phthisis, glycosuria, asthenic gouty di-crasia, and loss of tone from various causes.*

The irritations were such as arose from eczema, urticaria, pruritus, constipation, intestinal irritation, dyspepsia, ovarian neuralgia, chronic cystitis, and pain generally—whether of a neuralgic, rheumatic, or gouty character.

A condition of semi-tension of the arterial wall may be said to exist : namely, a pretty widely spread contraction in the sitting posture, and a constriction merely limited to the small arteries, with consequent expansion of the radial in recumbency (see p. 27). I have, moreover, frequently observed, that discomfort or pain may induce such a thorough tonic contraction of the arterial wall in all the postures,

* When asthenia was the predominant clinical condition, the radial calibre in the standing posture was often remarkably reduced.

as to render the radial calibre uniform; and when on the wane, this complete tension may give place to this less advanced form.*

3. *The Calibre Uniform in the Postures.*

IN health the calibre of the arteries is but rarely free from variation in the postures; and when this condition is observed, it is, moreover, quite transitory. On the other hand in clinical observation, I have met with this uniformity comparatively often; and not merely lasting for a short time only, but persisting for a while, or remaining apparently permanent. The radial calibre may preserve its form just as does the pupil of a damaged iris.

1. *Temporary uniformity* is of frequent occurrence. It may vanish under treatment; and may occasionally recur. The causes are obviously not organic. When

* In many cases of apparent increase of the calibre in recumbency, the artery enlarges just as the patient assumes this posture, but in a minute or so settles down to a lower point—either uniform with or below that of the sitting posture.

variation becomes apparent, the measurement of the major calibre almost invariably advances several points beyond that recorded when the bore of the artery remained uniform; and when the uniformity relapses, the calibre as a rule diminishes. I, therefore, conclude that in such cases the uniform calibre is caused by vasomotor constriction—persisting in the recumbent as well as in the other postures. As a rule, there is generally present some pathological condition of an irritative type: such as pain, gouty discrasia, eczema, lichen, constipation, &c.

According to my observation, the most frequent cause of this form of unvarying calibre is an increase of arterial tension due to gout; and when the tension is relieved by treatment, the postural variations return (see ch. iv., 2, and Part II., ch. iv., 3).*

2. *Persistent uniformity* characterizes an

* When plus tension is the cause of the uniformity of the calibre, the pulsations perceived by the finger placed over the artery beyond the pad are apparently increased while the calibration is being made (see Part II., ch. i., 3, and ch. ii., 2).

important group of cases. Here, according to my observation, the predominant cause does not appear to be tonic muscular constriction; but is more probably referable to organic changes in the arterial wall, which may cripple or may even annul vaso-motor action. It does not, however, follow, that the arterial tube in such a condition is necessarily rigid or fixed in calibre; for, I have frequently observed, that, though remaining uniform in posture, it may vary somewhat in calibre at different times—the fluctuations having apparently become limited and slow. Nor does this observation necessitate the existence of such a thickening of the wall of the artery as to be always obvious to the finger; for, in a large proportion of the cases there was no tactile evidence of arterial change. The cases, in which I have observed this persistent uniformity of the radial calibre, were the subjects of—

(1) Chronic interstitial nephritis.

(2) Arterio-sclerosis (including the physiological form—atheroma).

(3) Myxœdema (13 cases).

(4) Acquired syphilis (120 cases)*.

(5) Chronic gout.

In the *renal* cases the high intra-arterial blood-pressure alone might suffice to induce the continuous uniformity of the calibre; for I have observed, that—apart from any suspicion of organic changes in the walls of the arteries—a very moderate rise of blood-pressure will abolish the postural variations, which, moreover, reappear as it subsides (see Part II., ch. iv., 3). But I am persuaded, that this is not the sole cause in the majority of cases; as it is not improbable, that the uniformity of calibre is maintained by organic changes in the arterial wall as well as by the high tension; once set up, I have not known it to pass away—even though at times the arterial tension greatly diminished. Of other forms of chronic disease of the kidneys

* Of these cases over 53 were observed at the Lock Hospital, Harrow Road, W. When the infecting sore, or well marked secondaries, or tertiaries, were not present, there was a well defined history either of a hard chancre, or of undoubted secondaries.

I have had but a limited experience since I began this mode of observation. In waxy kidney (two cases only) postural variation of calibre was pronounced.

In *arterio-sclerosis* and in *myxædema* the cause of the postural uniformity is pretty obvious: namely, the thickening of the arterial coats. But the remarkable prevalence of the uniform calibre in the subjects of *acquired syphilis* was a surprise to me; for according to my observation, the cause producing it must be of quite general operation, and not such as to set up organic arterial changes in a case merely here and there—such as syphilitic obliterating endarteritis well known to pathologists. According to several trustworthy observers, syphilis “may be regarded as one of the most frequent causes of arteritis and its effects.”* The inner coat of the artery is the part chiefly affected:† so

* *Outlines of the Pathology and Treatment by Syphilis*, by Hermann von Zeissl, M.D., 1887, p. 274.

† *A Treatise on the Ligation of the Great Arteries in Continuity, &c.*, by Charles A. Ballance, M.B., M.S., &c., and Walter Edmunds, M.A., M.C., &c., 1891, p. 82.

that, it is quite possible, that the intima of the whole arterial tract may, in the first instance, become so damaged by the syphilitic virus as to cripple the physiological play of the tube; and it is conceivable, that the textural injury might be so slight as to readily elude detection by the finger. The after history may, however, in certain cases, reveal the development of advanced and palpable changes—such as obvious arterio-sclerosis and aneurism.* My opportunities for observation in cases of congenital syphilis have been too limited to enable me to form a definite opinion as to whether the same impairment of the arterial variation is as prevalent in this as in the self-acquired form of the disease: so far, however, I have observed a marked difference, the radial variation being quite normal in the cases of congenital syphilis I have examined.

* It is, I think, possible, that syphilitic arteritis may dispose to aneurism in two ways:—(1) damaging the arterial wall involved, and (2) inducing defective accommodation of the more peripheral arteries, so that effort and other similar causes may temporarily cause undue strain on the more central vessels.

4. *Restricted and Amplified Postural Variation.*

(a) *Restricted Variation.*—The radial calibre in health may present every now and then narrower variations in posture than is usual with the individual, *e.g.*, from 0·1 to 0·3 mm. only. An isolated observation of this kind may, therefore, have no pathological significance; but, when it becomes less or more persistent, I should refer it to minor organic changes in the arterial wall, or to the less pronounced forms of arterial tension. This observation I have frequently recorded in my elderly patients—in whom physiological arterio-sclerosis was doubtless developing, and now and then in those who presented a uniform radial calibre at other times.

(b) *Amplified Variation.*—In subnormal arterial tension I have several times observed a remarkable increase of the postural variation—the calibre varying even to the extent of 100 per cent.

5. *The Calibres of both Radial Arteries :
Asymmetry.*

WHEN in healthy subjects both wrists are equally favourable to observation, and the radial arteries are normally distributed. I have, as a rule, found the two vessels of equal or nearly equal calibre: the difference, when existing, not exceeding 0·2 mm. So that when there is observed a disparity of 0·5 to 1·0 mm., it may possess some clinical significance. I have measured such a unilateral reduction as this, as the result of (*a*) mechanical pressure (aneurism): or (*b*) vaso-motor constriction (distal irritation). In hemiplegia I have found the radial calibre enlarged on the paralysed side (see Part II., ch. iv., 4). I have observed that a well trained finger may be at fault in detecting minor differences than 0·6 mm. between the two arteries, and it is by no means always easy to appreciate with the finger those due to vaso-motor influence. The arteriometer would seem to afford not only a definite and record-

able reading in place of this undoubted uncertainty, but to favour the pathological study of the vascular reflexes, which may be confined to one side only.

6. *The Effects of Irritation on the Calibre of the Arteries.*

EVERY experimentalist is familiar with the fact, that when a sensitive nerve is cut across, the arteries immediately contract, and in consequence the blood-pressure rises.* I have observed, that the steps of an operation on man may in like manner produce fugitive contractions of the arteries which may be measured by the arteriometer, especially when the operation is an abdominal one. Fig. 4 gives the results of a series of observations on the radial calibre, made in rapid suc-

* The large fact of arterial constriction, the result of stimulation of various parts of the nervous system, is conclusively demonstrated in Sir Joseph Lister's paper *On the Parts of the Nervous System Regulating the Contraction of the Arteries*, Phil. Trans., vol. cxlviii.

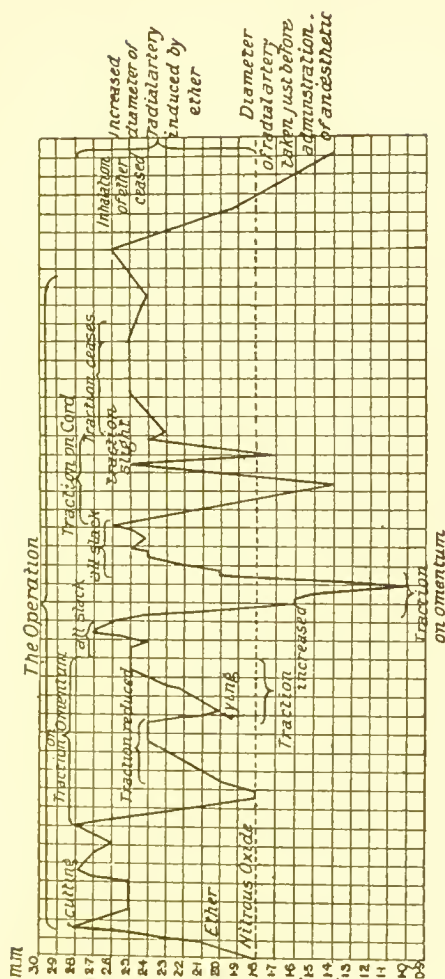


FIG. 4.—Diagram showing the effects of traction of the omentum and spermatic cord on the radial calibre during an operation for the radical cure of hernia. Each square = 2 minutes.

cession, throughout an operation for the radical cure of inguinal hernia, performed by Mr. Barker of University College Hospital. The calibre dipped sharply when traction was made on the impacted omentum, and on the spermatic cord, and when the cord was cut; and in the intervals when all was slack, it promptly rose again, and when the operative procedures ceased, it no longer fell.

In clinical medicine the arteriometer has likewise enabled me to observe, that contraction of the arteries of some area or other, or of the whole body, is the prominent effect of pain or irritation on the vascular system, the duration of the constriction being in proportion to that of the cause. It has seemed to me that any source of discomfort in the abdomen, and therefore in proximity to, and in direct communication with the great sympathetic system, produced a much more powerful reflex effect on the arteries, than when located elsewhere, *e.g.*, colon loaded, ovarian or uterine pain, inflammation, colic, &c. That contraction of the ar-

teries, arising in this way, is quite a common fact, has not escaped the clinical acumen of one good observer. In a recent valuable monograph (*The Physiology of Death from Traumatic Fever—a Study in Abdominal Surgery*) Dr. John Malcolm has brought this view prominently forward with much force and clearness. I will merely quote one of his “Conclusions as to the causes of the various pulse conditions found in fevers,” and refer the reader to the work itself. “The evidence seems very strong, that in traumatic fever, in shock, and in abdominal distension following a laparotomy, the small feeble pulse, whether slow or fast, is in no sense due to cardiac weakness, is not a condition beginning at the heart, but is an immediate effect of the contraction of the vessels.” In such cases a widespread constriction reduces the blood-pressure in the more peripheral arteries (including the radial), while it greatly increases it in the central ones: hence the vigorous throbbing of the carotids, which is not present when a feeble radial pulse

is due to cardiac failure.* Every one is familiar with the general clonic arterial contraction of angina vaso-motoria, of the rigor of malaria, of the hysterical attack, of migraine, &c., and many are equally conversant with the general tonic contraction of the arteries, which is a prominent feature in certain diseases of the nervous system, such as hysteria and allied ailments. In all such morbid conditions the arteriometer has afforded me a complete demonstration of the fact of general arterial contraction. But it has likewise repeatedly shown, that this vascular disturbance may be limited to one side only. Medical literature contains, so far as I know, but few references to this limited form of tonic arterial constriction. Sir W. Broadbent refers to an interesting and marked case of this type. "In a case of severe neuralgic pain along

* I have already referred to an experimental parallel of this clinical observation, namely, the great distension of the central vessels observed when the blood-pressure is raised in them by inducing contraction of the arteries (ch. iv., 3).

the sciatic, which was ultimately found to be due to a malignant growth in the spinal canal, which I once saw, there was unilateral arterial spasm, giving rise to a perceptible difference in the pulse of the two sides, which resisted the influence of nitrite of amyl. One side only of the face flushed.”* Dr. Thomas Oliver, of Newcastle-on-Tyne, has likewise made some instructive observations on the unilateral effect of lead colic on the radial pulse. “Admitting that even in health there is a degree of difference in the fulness and tension of the two radial pulses, this difference in lead colic is so pronounced as to stand out prominently as something peculiar to the illness like the inequality of the pupils, it stands in some way related to primary disturbance of the abdominal sympathetic fibres, and through them of the vasomotor centre.”† But the arteriometer

* *The Pulse* by Sir W. H. Broadbent, Bart., M.D., F.R.C.P., p. 154.

† *The Goulstonian Lectures on Lead Poisoning in its acute and chronic forms* by Thomas Oliver, M.A., M.D., F.R.C.P., 1891.

has enabled me to observe, that inequality of the two radial arteries, from contraction of one of them, set up by some distant source of irritation, is not a very uncommon clinical fact; and when it does occur, the temperature, as a rule, falls on the side of arterial reduction.†

The following are a few examples of reflected unilateral arterial constriction quoted from my notes :—

† See a paper by the writer in *Practitioner*, August, 1893.

A. B., a professional brother, *circa* 35 years of age, severe right hemicrania (? migrainous) :

Attack.		After attack.	
Right.	Left.	Right.	Left.
Diameter in mm.	1'6	1'7	2'0
Expansile reaction	normal	normal	normal

A. C., æt. 59; left lumbar pain (? renal calculus) ; has passed several calculi.

Less pain.		No pain.	
Right.	Left.	Right.	Left.
Diameter in mm.	1'8	1'5	1'5
Expansile reaction	normal	normal	normal
Temp. sublingual	97'7	98'0	98'0

B. K., æt. 20; severe neuralgia of left arm for six months.

Less pain.		No pain.	
Right.	Left.	Right.	Left.
Diameter in mm.	1'3	1'8	1'8
Expansile reaction	normal	normal	normal
Temp. sublingual	96'7	98'4	98'5
Pupils	less mobile	equally mobile	equally mobile

A. T., æt. 58; for a week has had severe pain in left hypogastrium with rigor, now there is only a slightly tender swelling in left inguinal region.

Less pain.		No pain.	
Right.	Left.	Right.	Left.
Diameter in mm.	1'9	1'5	1'5
Expansile reaction	normal	equal	equal
Temp. Sublingual	97'2	97'2	97'2

7. The Standard Calibre, and some of the leading Pathological Deviations.

THOUGH the mode of observation I follow mainly depends on the determining of variations (if any) of the calibre of the same artery, and not on a comparison with a standard or mean measurement, some clinical advantages do arise from acquiring a general notion of the average maximum measurement, which may be furnished by a large number of observations in different individuals: for, in certain morbid conditions, the radial calibre is apt to be considerably reduced or increased; and then the data provided by the arteriometer may prove of some use in diagnosis and treatment. Still, it will be borne in mind, that a reference of the calibration of any particular case to an average measurement should only be made in quite a general way: as size and build of the individual, idiosyncrasy in respect to the calibre of the arteries, and variations of the radial

itself and of its surroundings require to be kept in mind. According to my observation the average maximum calibre of the radial artery in men varies from 2·0 to 2·5 mm., and in women from 1·8 to 2·3 mm.

The following have seemed to me to be the leading pathological causes of pronounced variation.

1. DIMINUTION.—I have observed that the radial calibre may be reduced by (*a*) vaso-motor constriction, (*b*) passive shrinking, and (*c*) organic contraction.

(*a*) *Vaso-motor constriction* is best seen in neurasthenia, hysteria, hypochondriasis, asthenic gout, &c.—and especially in the active postures. It is often set up by a distal source of irritation (see p. 48).

(*b*) *Passive reduction* from mere shrinking of the wall is observed in all diseases that impair the general health and the nutrition of the blood, or lower the heart's action.

(*c*) *Organic reduction* is found in the obliterating forms of arterio-fibrosis and endarteritis met with in atheroma (some

cases probably forming a variety) ; in the second and tertiary stages of syphilis ; and in chronic gout.

2. ENLARGEMENT.—An exceptional increase has seemed to me to be most frequently associated with (a) *Augmented resistance* limited to the vessels of smaller size than the radial, as in some cases of chronic interstitial nephritis, and in chronic gout ; (b) *Loss of elasticity* of the arterial wall favouring dilatation of the arteries as in one form of atheroma ; and (c) *Relaxation* of the arterial walls, not unfrequently observed in large obese and plethoric subjects.

Any marked deviation observed in any particular case may be the product of the co-operation of two or more causes.

8. *The relation between the Calibre and the blood-pressure.*

IN a large number of cases—especially of chronic gout and renal disease—I have observed, that the radial calibre diminishes

as the blood-pressure rises and *vice versâ* (see Part II., ch. iv., 3). But this relation is by no means invariably maintained. In elderly subjects more especially I have repeatedly found, that the radial calibre may increase or diminish in direct proportion to the blood-pressure; of this the following is a good example:—

Mrs. N., æt. 71; liable to sudden accessions of blood-pressure, when the bowels fail to be properly relieved. Postural variation nearly lost:—

RADIAL CALIBRE.	OBLITERATING BLOOD-PRESSURE*.
2·4 mm.	280 grammes
2·3 „	260 „
2·0 „	230 „
1·8 „	220 „
1·5 „	200 „

In these cases of direct relationship, it is not I think improbable, that the blood-

* Determined by the writer's pulse-pressure gauge (see Part II., ch. i.).

pressure is incited to rise from increased resistance set up in the terminal arteries, and the vessels of larger size—like the radial—merely become dilated, because the muscular contractility is insufficient to resist the distensile force of the augmented blood-pressure.

CHAPTER IV.

RADIAL MEASUREMENT IN RELATION TO
DIAGNOSIS, TREATMENT AND THERA-
PEUTIC ENQUIRY.1. *The Arteriometer in relation to Diagnosis.*

It seems to me not improbable, that there may arise now and then occasions in which some doubt exists in respect to diagnosis, when the arteriometer may prove useful: as in Bright's disease; myxœdema; syphilis; gout; angina pectoris; and atheroma.

(a) *Bright's disease.*—The cases of acute, as well as of chronic Bright's disease, which I have examined with the arteriometer, having afforded a uniform radial calibre in posture, it is possible, that this clinical fact may be made available in deciding on doubtful cases of albuminuria: for, should the postural variations be ample in any particular case, the other negative evidence in respect to renal disease

may thus find corroboration; or should they be absent, or greatly restricted, the observer may thus be put somewhat on his guard in expressing a favourable opinion, especially if other signs are somewhat suspicious, and there is no history of acquired syphilis. In the convalescence from acute nephritis I have found, that calibration of the radial artery may likewise afford a definite hint as to whether the disease is clearing up, or is gradually merging into chronic renal disease.

(b) *Myxædema*.—Uniformity of calibre may not improbably prove useful in contributing to decide on a doubtful case; perhaps doubtful, from being in an early stage of the disease.

(c) *Syphilis*.—The absence of the normal postural variation of the radial calibre in the subjects of acquired syphilis has led me to take this observation into account when deciding on an obscure history: for instance, when there is merely an admission of there having been a sore or something venereal at some time or other—but no subsequent development of well marked

secondaries ; or when the history points somewhat obscurely to secondaries ; or when a patient is reticent of the past ; or when circumstances render the enquiry difficult or undesirable—as in the case of a woman who may be ignorant of the cause. Such a doubt not unfrequently hangs round a case of locomotor ataxy, or of an obscure condition of the nerve-centres, or of questionable skin disease, or of rebellious ulceration, &c. Under all these conditions of uncertainty with regard to acquired syphilis as an ætiological factor, the arteriometer has seemed to me to offer some clinical service ; for, according to the evidence which I have collected *so far*, when it pointed to a positive conclusion, this inference was certainly rendered probable by some collateral evidence, or was undoubtedly confirmed by the issue of treatment ; and when it failed to support the probability of a specific condition, that view coincided with either the denial on the part of the patient of syphilis ever having been contracted, or the total absence of any confirmatory indications past

or present. Guided by the observations I have made, I certainly would be disposed to hesitate to entertain the specific nature of a doubtful case, if the postural variations were observed to be normally ample: and if they could not be detected, or were found to be restricted, to 0.1 mm. or so, the observation would be of but little suggestive value, until other causes of uniformity or of great restriction were excluded, and until subsequent observations showed that the condition of the artery was a persistent one (see p. 36). If, however, the calibre were much below the standard size (p. 51), a suspicion in favour of syphilis might be entertained; for, I have detected a great reduction, even amounting to from 25 to 50 per cent., in a large proportion of the cases of chronic syphilis which have come under my observation. But of course it is needful to keep in mind the other causes of a small unvarying calibre (see pp. 51, 52).

A clinical reminder of this kind is of some practical value; for it keeps the mind alert to look out for, and to direct

enquiry in search of this important fact in the personal history—important especially from the therapeutic standpoint. By means of the arteriometer I have over and over again detected evidence of the foot-prints, as it were, of syphilis in the arteries, when no other clinical clew existed, and when the enquiry unearthed the fact of a chancre, which existed perhaps twenty or thirty years before, but which had been lost sight of, because the recollection of it had not been maintained or revived by the development of any sequelæ. This mode of observation has enabled me many times to demonstrate to my own satisfaction, that an infecting chancre, though it may not have induced secondary and tertiary manifestations, or congenital syphilis in the progeny, has, nevertheless, left its impress on the arterial wall, as shown by the permanent uniformity of the radial calibre in posture; and I have observed that so long as this remains without serious reduction, the general health in such cases, as a rule, continues apparently unim-

paired. I have met with several instances of this kind in medical men, in whom the diagnosis of the hard chancre was well attested.

While these pages are passing through the press, I am observing two cases of rheumatic gout (rheumatoid arthritis), which illustrate this position. In both, the arteriometer not only suggested the enquiry which revealed the history of a chancre (in one dating 30, and in the other 20 years ago), but thus provided a probable explanation of the resistance of the cases to the well-devised treatment that had been previously followed, and furnished a new and promising turn to the application of remedies.

(*d*) *Gout*.—My work at Harrogate brings me much in contact with gout—especially in its chronic forms. I have, therefore, had ample material for the application of this mode of observation to this disease. In undoubted chronic gout I have almost always found the radial calibre to be invariable and reduced; and in the exceptional cases in which it varied at all in

posture, it did so but slightly, and became uniform whenever symptoms or signs of gout appeared. In the absence of acquired syphilis and of arterio-fibrosis, I have, therefore, been led by observation to regard a reduced and unvarying radial calibre as a useful diagnostic sign strongly suggestive of the gouty diathesis. All the cases in which it was present were either positively gouty, or were very suspiciously so; and were regarded by their medical attendants as gouty; and gout was certainly a prominent feature in the family history.

I have, however, observed, that when asthenia is a prominent feature in the gouty, or in the *quasi* gouty, especially in women, the radial calibre is apt to increase in recumbency, either for a few minutes only, or for a longer period.

According to my observation, rheumatism and chronic rheumatoid arthritis differ, as a rule, in this respect from gout; for in both these ailments postural variations of the radial calibre were apparent. Now and then, however, in rheumatoid

arthritis they were absent, when suspicious signs of true gout were presented by the patient, or a family history of that disease was elicited; and the same fact was observed in many cases of *quasi* rheumatism—especially muscular rheumatism—which was obviously of gouty origin.

(e) *Angina pectoris*.—In the cases of undoubted angina pectoris which I have examined, I have found the radial calibre uniform in the postures; but in several instances of *quasi* and doubtful angina I have observed considerable postural variation, and the favourable issue of treatment in such cases has gone far to disprove the existence of the grave disease. I am, therefore, disposed to regard the presence of radial variation in a case of this kind as a favourable sign.

(f) *Atheroma*.—Advanced or fully developed atheroma is of course easy to recognize. I have, however, found the arteriometer of service now and then in detecting the earlier and ill-defined stages of it. It has likewise seemed to me of clinical value in distinguishing two forms,

which cannot be accurately defined with the finger: namely, one in which the calibre is much reduced—though the artery and the pulse may not seem to the finger to be less than normal; and the other in which it is increased. I have observed that the contractile form is sometimes associated with imperfect cerebration in the aged: as when a sub-normal calibre becomes further lowered by any cause that may suddenly depress the general health, such as the shock of a surgical procedure. I have seen an elderly patient of this type continue for several weeks after an operation in a befogged mental condition, without fever or other obvious cause, with a radial calibre of from 0·5 to 0·7 mm.; and gradually emerge with recovery of the mental faculties when the calibre had risen—with rest and good nourishment—to 1·5 mm.*

Inasmuch as it is well known that organic arterial changes are apt to develop inequally in different regions, this fact

* Such a case as this I observed in Middlesex Hospital through the courtesy of Mr. Henry Morris.

should, of course, always be borne in mind in drawing an inference from evidence derived from the radial arteries alone. It has, however, seemed to me, that with regard to atheroma, a very slight degree of textural change suffices to restrict, and even to annul the play of the radial wall, and I am disposed to think, that it is not likely to become advanced elsewhere without some implication of the radial arteries, which the arteriometer will reveal.

2. *The Arteriometer in Relation to Treatment.*

I. THERE are one or two points in which I have found that calibration of the radial artery may in a general way prove suggestive in *the management of cases*.

(a) When the maximum calibre is persistently or generally apparent in recumbency, tonic medication and rest are specially indicated, though now and then these measures may be advantageously combined with correctives.

(b) When, apart from syphilis and

myxœdema, the normal postural variations are abolished, or are greatly restricted, tonics (such as iron, strychnine, &c.), are, as a rule, badly borne, and may prove injurious. In this class of cases it not unfrequently happens, that corrective treatment is attended with the happiest results, and constipation—even though comparatively slight—is generally more pernicious than when the postural variations exist.

(c) In prescribing rest, exercise, and massage, the arteriometer may afford useful hints. I have observed, that a great reduction of the radial calibre will take place in the standing posture, when the ventricular action is much below par; it may even become fifty per cent. less than in the sitting or recumbent postures. Then I have found it to be a good working rule to limit the exercise, or to adopt some passive form of it, or to prohibit it entirely for a time. When in such cases the maximum calibre is persistently present in recumbency, I have observed much benefit to arise from the adoption of recumbent rest,

either absolute, or systematically resorted to in the intervals of exercise. In prescribing massage the arteriometer may point to the form in which this mode of treatment may be most advantageously applied to a particular case: for instance, when the artery is small and contracted, effleurage and tapotement are more especially indicated, and should either take a prominent place in the procedure, or should be the only methods adopted; and when the vessel is full and tense, pétrissage will probably yield most benefit (see p. 18). I fear that massage—which is undoubtedly a valuable therapeutic measure when properly and judiciously prescribed—is being much discredited by the empirical and indiscriminate way in which it is practised.

(*d*) There is no department of clinical observation in which I have found the arteriometer of more use than in prescribing baths. Bathing undoubtedly exerts a powerful influence on the vascular system, and through it on the general health. It should, however, be adjusted to the conditions of the circulation present in

each individual, if the benefits it can confer are to be obtained; otherwise it may prove injurious. I have observed, that all warm forms of still bathing—such as the Turkish bath, vapour bath, warm and hot immersion baths—reduce the arteries for a time; and in this they form a superficial resemblance to the effect of pétrissage on the arteries (see p. 18), only the reduction they produce is obtained by surcharging the periphery, and not from clearing it. In the Turkish bath the excess of blood congesting the peripheral vessels is got rid of by pétrissage and by the spray-bath, or by the cold dip. When such procedures do not follow a hot bath, there is generally experienced some languor and depression, which arise from the temporary reduction of the arteries and the clogging of the periphery with an excess of blood; and horizontal rest favours the readjustment and restoration. I have frequently observed, that when there exists already some peripheral embarrassment—as when in gouty subjects there is an absence of the postural vari-

ations—this form of bathing is apt to prove very injurious; often aggravating the depression and langour that exist, or even inducing an attack of active gout. On the other hand, undoubtedly the form of bathing which secures the most thorough passage of blood through the periphery is the Aix-les-Bains douche; for, the douching, which in principle is effleurage, or tapotement *plus* warmth, greatly favours arterial dilatation, and the easy passage of the blood to the periphery, and the manipulations assist the flow through it.* A bath of this kind may, however, reduce the arteries; but the reduction is due to a clearing of the periphery, and differs from that of the “still” hot bath, and merely requires horizontal rest for restoration. When about nine years ago I introduced the Aix-les-Bains douche

* The method of massage adopted in the douche bath is quite different from that usually employed after a Turkish bath; for it is light and vibratory, and resembles effleurage and tapotement in its physiological effects, while the manipulative procedure of the Turkish bath is less or more firm and squeezing, and partakes of the nature of pétrissage (see p. 18).

treatment into Harrogate as an addition to the bathing procedures there adopted, there were no facilities for returning patients in the horizontal posture to bed as at Aix-les-Bains; and consequently that part of the treatment could not be observed. I soon found, that this omission was by no means immaterial; and I became dissatisfied with my early results. I then prescribed the Harrogate needle-bath—warm to cool or cold—as a routine conclusion to the procedure; when my patients began to flourish to my satisfaction.* The explanation of this experience is not far to seek; for, the needle-bath being but a delicate and effective way of securing the physiological effects of effleurage and

* The Aix-les-Bains douche in this modified form has become so much in request, that the Corporation of Harrogate are now spending £65,000 in the erection of a new bathing establishment, in which it may be most efficiently applied. The Harrogate massage-douche is undoubtedly a valuable form of masso-therapeutics with a great future before it. My observations have shown that no other form of bathing can approach it in its power to restore the physiological play of the arterial wall when impaired or lost, and that it is most useful in the treatment of all forms of chronic gout.

tapotement on the arteries, at once restored the arterial fulness and provided the final touch for the readjustment of the circulation. I have found this form of bathing, modified to the individual requirements of the circulation, of great service when postural variations were restricted or abolished from the presence of some form or other of increased peripheral resistance. When the calibre increased in recumbency the various modifications of the Harrogate needle-bath have, as a rule, yielded the best results. It is, however, difficult to particularize in a few lines the leading indications to be learnt from the readings of the arteriometer for the selection of baths; I must, therefore, content myself with these brief references, as mere illustrations of the physiological basis on which the judicious prescription of baths should rest.

2. In observing *the effects of treatment*, I have likewise found the arteriometer useful.

(a) The recorded calibrations have shown that the maximum calibre observed

in the sitting posture is, as a rule, directly proportionate to the state of the general health; a progressive rise, *if accompanied by the normal postural variations*, coinciding generally with well-being and improved nutrition.; and a persistent reduction, whether the normal postural variations be present or absent, accompanying other signs of retrogression, and perhaps loss of weight. This mode of observation, therefore, appears to reveal a fundamental fact of vitality, being a general gauge of the amount of arterial blood supplied to the tissues.

(b) Progress may even be traced by the arteriometer, when the postural variations are absent, or are greatly restricted; for, when the arterial wall is not organically involved, they may return, or may develop in the course of treatment, in proportion as the arterial tension is reduced, or the causes of irritation, maintaining constriction of the vessels, are removed or modified.

I have found this position abundantly proved in regard to gout, and it would

be an easy matter to illustrate it by a long series of cases. The few examples quoted on p. 141-3 will probably, however, suffice. The agents which I have observed to be most effective in determining this beneficial change—and they are those with the use of which I am most familiar—are (*a*) massage, especially in the form of the Harrogate massage-douche; and (*b*) aperient salines, such as a course of the Harrogate sulphuretted and ferruginous salines. In many cases I found that the massage-douche alone sufficed to restore completely the postural variation of the arteries, and that this remedial effect was not merely immediate and temporary, but less or more continuous. Doubtless it will be observed that other modes of treatment will also prove effective in this direction.

Postural variation, however, remains in abeyance under treatment, when it is due to organic changes in the arterial wall; but even then calibration may afford evidence of improvement by recording an increasing diameter. I have repeatedly observed this fact in the treatment of

atheroma obliterans, myxœdema, and syphilis, the mere enlargement of the calibre being accompanied by other indications of improved health and vigour.

In *syphilis* the radial calibre is frequently very much reduced, especially after the lapse of several years since the date of infection; and especially too when the disease is producing its secondary and tertiary manifestations. It is I think not improbable, that in many cases there may be some causal connexion between the reduced calibre of the arteries and these more remote effects of syphilis. I have, however, observed several times a marked reduction of the radial calibre without the appearance of any of the ordinarily recognized developments of the disease; but associated with a considerable reduction of elasticity and vigour, and other signs of lowered nutritive activity of the nerve-centres. Patients thus affected were said to be suffering from neurasthenia, and general debility: and though the fact of syphilitic infection in the past was well known, it was not suspected that it had

any causal relation with the lowered general health. The arteriometer, however, demonstrated the presence of one condition common to all the cases—those of obscure nervous debility, and those in which syphilis was obviously manifesting its presence; namely, a greatly diminished radial calibre: and on submitting them to treatment by mercurial inunctions and sulphur baths,* or by the administration of small doses of mercury by the mouth, the calibre, as a rule, not only progressively increased, but the nervous system and the general health acquired an accession of tone and vigour, and the more obvious signs of the specific disease receded and even vanished. I have tabulated a few of the observed results recorded in my notes. In such cases I have, therefore, learnt to accept the evidence provided by arteriometric observation, as affording an im-

* At Harrogate the treatment of syphilis by sulphur baths and inunction of mercury, on lines similar to those adopted at Aix-la-Chapelle, has been efficiently carried out for some years past. So far I have been well satisfied with the results observed.

CASES OF SYPHILIS TREATED BY MERCURY.

IN TREATMENT.

75

AGE.	LEADING MANIFESTATION.	INFECTING CHANCRE YEARS AGO.	RADIAL CALIBRE.		DURATION OF TREATMENT.
			BEFORE TREAT- MENT.	AFTER TREAT- MENT.	
47	Syphilide	1	1'3	2'0	28 daily inunctions and baths.
39	{ Ulceration on Nose (Rupia)	5	1'3	1'7	21 daily inunctions and baths.
45	{ Incipient Locomotor Ataxy	7	1'1	2'2	{ 21 daily inunctions and baths. Then twice a week for 9 months.
40	Obstinate Neuralgia	8	1'3	1'8	21 daily inunctions and baths.
46	Ulcer on Tongue	20	1'4	2'1	31 daily inunctions and baths.
45	{ Neurasthenia ob- scure nervous sym- ptoms	23	1'2	1'9	{ Inunctions followed by Pil. Hydrarg.
33	Neurasthenia	11	1'3	1'7	11 days every night.
42	Incipient Locomotor	23	1'4	2'2	{ Every night for alternate fortnights during 5 months.
56	Vertigo	27	1'1	1'6	21 days.
42	Alopecia	27	1'3	1'7	21 days.

Mercurial Inunctions and Sul-
phur Baths.

Pil. Hydrarg.
gr. j. o n.

portant guide in treatment ; in determining for example, the dose of the remedy, the progress of the cure, and the duration of it. My observations have satisfied me, that the minimum effective dose by the mouth needs to be but small—smaller indeed than that ordinarily prescribed—and it would seem that the duration of the treatment should be very prolonged : in a word they amply confirm Mr. Jonathan Hutchinson's teaching on these points. If the foot-prints* of the disease in the arteries are to be effaced, or to be efficiently counteracted, the mercurial treatment should be extended over years, either continuously or with intermissions ; for all the cases, which had been subjected to fairly prolonged, and what might be generally regarded as thorough treatment, nevertheless presented a uniform radial

* The arterial changes are doubtless the product of a bygone result of syphilis ; and cannot be regarded as an indication of the presence of the disease itself. Shrinking of the calibre—leading to reduced nutrition of the blood and of the tissues and organs, and to lowered vitality generally—is the evil to which the artery seems to be most prone.

calibre. But even in such cases the further use of mercury by inunction and sulphur baths enlarged the calibre. More extended experience is needed, in order to decide whether a sufficiently prolonged treatment can accomplish the happy result of restoring the postural variations.* In the meantime, however, guided by the facts I have observed with the arteriometer, I am satisfied, that in syphilis (1) the arteries, after the cessation of mercurial treatment for some time, are extremely apt to shrink in calibre; and are more especially prone to do so on the occurrence of causes, which impair the general health: and (2) mercury

* I have occasionally detected a slight postural variation, (*e.g.*, 0.1 or 0.2 mm.), when the radial calibre attained 2.0 mm., or more than 2.0 mm. I am, therefore, disposed to hope, that more extended treatment than has ordinarily been applied may eventuate in further improvement in this direction. There is, I think, good grounds for the belief, that it is frequently advantageous for those who have even undergone good and prolonged treatment, to submit occasionally to subsequent short courses of inunctions and sulphur baths; for such after treatment may, in a timely way, counteract the slow contraction, to which the arteries of the syphilitic are liable for many years after the primary infection.

is the surest and best remedy to counteract this pernicious effect of the disease.

The liability of the arterial wall to reduction, which I have observed in syphilitic subjects, when the health is disturbed or lowered by any cause—such as worry or some passing ailment—may in some cases form a bar to recovery when the patient is treated by ordinary remedies; but, on the application of antisyphilitic treatment, the arteries may enlarge, and in consequence the health may improve, and any intercurrent malady present may thus be thrown off more readily.

These observations have greatly confirmed my faith in mercury as a remedy in syphilis. I am persuaded, that when properly administered, it will effect a real cure; and that in the syphilitic it follows the lines of a true tonic, enlarging the arteries and increasing the number of red corpuscles, thereby raising oxidation and improving nutrition generally.

I cannot say as yet what is the general effect of the iodides on the syphilitic artery; for my opportunities of observa-

tion with them have not been sufficiently numerous to enable me to draw a reliable conclusion.

(c) When the maximum calibre is habitually present in recumbency—as in anæmia and various forms of debility—I have found it most instructive to trace with the arteriometer the progress of restoration; the radial calibre increasing until its maximum development was attained in the sitting posture, while it correspondingly diminished in recumbency. The great value of recumbent rest in the treatment of such cases was thus forcibly demonstrated; though, as a rule, the rest prescribed was not absolute, and was only such as alternated with exercise, which was not unduly restricted. The amount of benefit achieved by this simple means, suggested by the physiological truth brought to light by the arteriometer, seemed to me to be far greater than that sometimes derived from a long course of tonic medication. A few examples are quoted from my notes on subsequent pages (pp. 136-8). Among the cases of this type the arteriometer has not

unfrequently afforded data that suggested the right line of treatment to be adopted, when the ordinary clinical indications seemed inconclusive. A good example of this kind I lately observed in a gentleman aged 30, suffering from great drowsiness; he would fall asleep at his desk, and had a great difficulty in keeping himself awake while going about. There was no apparent cause of this condition—though it was suspected by his medical attendant that it was due to derangement of the liver. The arteriometer, however, showed that it probably arose from a very greatly reduced supply of blood to the brain in the sitting posture; for in that posture the radial calibre did not exceed 1·0 mm., whereas in recumbency it measured 2·0 mm. Treatment by recumbency, needle-baths and tonics in 19 days completely reversed the measurements of the radial calibre in posture, and at the same time removed the unwonted drowsiness.

3. *The Arteriometer as an Aid to Enquiry.*

A FIELD for arteriometric observation is presented by the action of remedies on the arteries of man; and I have found that it may supply useful hints bearing on therapeutics, and especially on the effective dose of certain remedies. I have observed too, that it may reflect some light on such unsettled questions as the effects of anæsthetics on man; and, on testing in a preliminary way, the action of new remedies and products, it may suggest the lines of experimental enquiry in animals. In illustration, I will quote the results of some observations I have made on the effects of anæsthetics, and of some auto-genous products—the extracts of the grey matter of the brain, of the thyroid gland, and of the supra-renal capsules—on the radial calibre.

1. *Anæsthetics* (ether, chloroform, nitrous oxide, A. C. E. mixture), either enlarge or diminish the calibre (see fig. 5). Ether invariably increases it, and chloroform

reduces it—the rise or fall lasting with but slight fluctuations throughout the administration. Nitrous oxide causes a

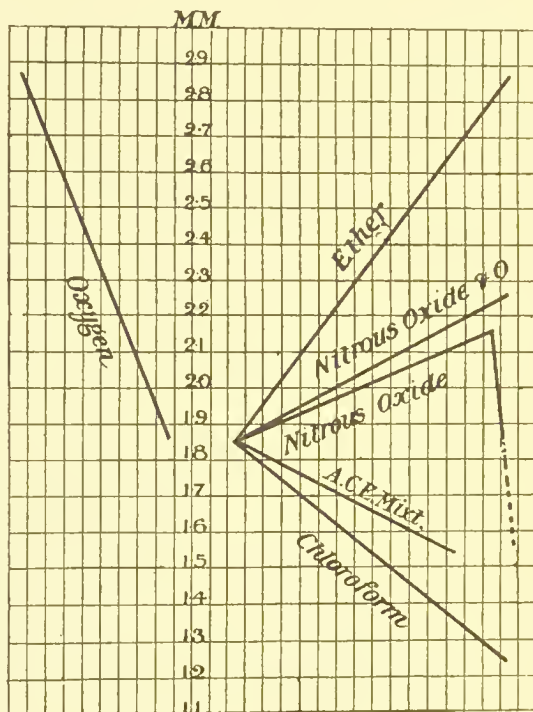


FIG. 5.—Diagram showing the average results of observations on the effects of anæsthetics on the radial calibre.

slight expansion, followed by a reduction either to the normal calibre, or to a point

or two below it ;* the latter, however, fails to take place when the gas is inhaled along with oxygen.† Oxygen enlarges the calibre. The A. C. E. mixture reduces it, but to a less degree than chloroform.

Inasmuch as I have shown (pp. 42-44) that operative procedures are apt to throw an increased strain on the heart and great vessels by causing extensive contraction of the middle and smaller sized arteries, it would seem to follow that those anæsthetics will be the safest that maintain

* I have tested the radial calibre under nitrous oxide administered by different anæsthetists, and I have observed, that the drop below the normal calibre need not necessarily take place: as a rule, for example, it was not apparent in the cases under the administration of the gas by Dr. Dudley Buxton, at the Dental Hospital, Leicester Square.

† The mixed gases were administered at the Dental Hospital, by Dr. Frederic Hewitt, who advocates with much clearness the advantages to be gained from this combination, and informs me that he has given it with much satisfaction in from 2000 to 3000 cases. See *Anæsthetics and their Administration*, 1893, and *On the Anæsthetic Effects of Nitrous Oxide when Administered with Oxygen at Ordinary Atmospheric Pressures; with remarks on 800 cases*, 1892.

the heart's action and the fulness of the arteries. I therefore conclude from these observations, that ether for ordinary surgical work, and nitrous oxide with oxygen for short operations, best fulfil this physiological requirement, and that as a general anæsthetic the A. C. E. mixture is preferable to chloroform.

2. *The extracts of the grey matter of the brain, of the thyroid gland, and of the supra-renal bodies,** when administered to healthy subjects by the mouth, affect the radial calibre; the brain and thyroid extracts enlarging, and the supra-renal extract diminishing it.

I have observed, that *thyroid extract* in *small* doses not only enlarges the radial calibre, but reduces for a time the frequency of the pulse†; and I have likewise

* I am indebted to Messrs. Willows, Francis and Butler, 101 High Holborn, for their aid in preparing for me an excellent dry extract of the cortex of the brain of the sheep, which I am prescribing with promising effect in conditions of malnutrition of the nerve-centres, and also for their liberal supply of supra-renal extract for the experimental work here referred to.

† When thyroidism is induced the temperature rises and the pulse-rate increases.

found, that in myxœdema it increases the radial diameter, without, however—so far as my observations have extended—restoring the postural variations.* In syphilis the radial calibre also enlarges under thyroid extract, but it appears to me to do so more slowly than in myxœdema; and I have observed, that quite diminutive doses (℥ i.-iij.) twice a day, may maintain a marked acceleration of the heart's action—*e.g.*, 130 per minute—or may even set up a slight febrile movement; but notwithstanding this abnormal stimulation of the heart, I have seen the general health improve, and the weight increase. From the few observations I have lately made, I am disposed to think, that small doses of thyroid extract may prove useful in the treatment of syphilis; when, for instance, the calibre of the arteries does not increase, and progress is not apparently made—notwithstanding the administration of mercury; though this drug will always hold the

* The cases I have observed had been under thyroid treatment for several months or a year.

first place as an anti-syphilitic remedy. It is possible that thyroid extract—when the dose is duly adjusted—may raise the nutritive processes by increasing the supply of arterial blood to the tissues, when the pathological conditions involve a reduction of the calibre of the arteries, and it may thus counteract or annul certain morbid processes of diverse origin. Hence probably the promise of benefit which it affords in the treatment of such widely different diseases as syphilis (secondary and tertiary stages), cancer, psoriasis, lupus,* and senile cerebral anæmia (from atheroma obliterans).

Having observed that the radial calibre is reduced by *supra-renal extract* (m xv. = gr. xv. of supra-renal capsule by the mouth) I was led to determine whether contraction of the arteries resulted from injection of the extract into the veins of animals; and Professor Schäfer of University College, London, and myself are now

* See, *A Clinical Lecture on two Cases of Lupus treated by Thyroid Extract*, by Byron Bramwell, M.D., F.R.C.P., *Brit. Med. Journal*, April 14th, 1894.

engaged in an experimental enquiry "On the Physiological Effects of Supra-renal Extract" in which we have conclusively proved this fact.* It is but natural to

* The following are some of the leading results of the enquiry:—

The intra-venous injection of the extract equal to 3 grs. of the gland produced in the dog (1) a remarkably pronounced rise of blood pressure, doubling or even trebling that recorded prior to the injection; (2) powerful contraction of the arteries as shown by the plethysmograph applied to the limbs, the oncograph enclosing the kidney, and the arteriometer applied to the bared femoral artery—this effect, taking place even though the cord and brachial plexus were cut, was apparently of peripheral origin; (3) stimulation of the vagus; (4) stimulation of the cardiac muscle.

The characteristic properties of the extract are not impaired by boiling; and they are not due to the proteid elements, or to neurine (as has been conjectured), but probably arise from the presence of an alkaloidal body. Alcohol, whether absolute or rectified, extracts the active principle. See *Four. of Physiol.*, 1894.

In his Presidential address to the Physiological Section of the meeting of the British Association, held at Oxford, this year, Professor Schäfer thus refers to this enquiry. "The results which were obtained show that there is present in both alcoholic and watery extracts of the gland a most potent physiological substance, which when injected into the body of an animal produces, even in minute doses, a remarkable effect upon

turn first of all to Addison's disease, as affording a promising field for the therapeutic application of a supra-renal preparation.* I have seen but two cases,

certain parts of the nervous system, upon the muscular system, upon the heart, and upon the blood-vessels. If only as much as a grain by weight of supra-renal capsule be extracted with alcohol, and if this alcoholic extract be allowed to dry, and then be re-dissolved in a little water or salt solution and injected into the blood of a dog, the results which are obtained, considering the minute amount of substance added to the blood, are certainly most extraordinary. The nervous centre which regulates the action of the heart is powerfully affected. * * * * * This is accompanied by a strongly marked influence upon the blood-vessels, and especially on the arterioles. The walls of these are chiefly muscular, and the drug exerts so powerful an action upon this muscular tissue as to cause the calibre of the vessels to be almost obliterated. The heart being thus increased in force and accelerated, and the calibre of the vessels almost obliterated, the result is to raise the pressure of the blood within the arterial system to an enormous extent, so that from a blood-pressure which would be sufficient to balance a column of some four inches of mercury the pressure may rise so high as to be equal to a column of mercury of twelve or more inches. . . . We have to do here with a substance which is as potent, although in a different direction, as strychnia."

* Messrs. Willows, Francis and Butler have prepared

previously diagnosed as supra-renal, which I have treated for three months with encouraging results. In both I observed a gain in weight, an increase of the radial calibre,* the transference of the maximum calibre from the recumbent to the sitting posture, a lessening of the pigmentation, and the disappearance of nausea and anorexia. One of the patients was sent to me by Dr. Mackern of Blackheath, who thus reports her present condition:—"The pigmentation now is not very noticeable; the cardiac murmur, and the venous murmurs in the neck have disappeared;† the patient is able to walk

for me a tincture of the supra-renal bodies, which contains all the active properties, as proved by experiments on animals. mj. is equal to gr. j. of the gland. I now propose pilules containing 1 gr. of the dry extract = 15 grs. of the gland.

* This observation shews that the effects of the supra-renal preparation on the calibre of the arteries in Addison's disease differ from those observed in health; possibly because the cachexia and anorexia of that disease induce passive shrinking of the arteries (see p. 51) which will give place to enlargement as the health is improved (see p. 70, 71).

† This patient was very anæmic, and was treated

about with comparative ease; and is in fact in every respect a resurrection."

The physiological effects of the extract suggest, however, a much wider therapeutic range. The experiments show that it possesses to a high degree the power of contracting the arterial walls.* This property may be curatively useful in various forms of vaso-motor relaxation and paresis—such as those which may be met with in the menopause, in exophthalmic goitre, in functional or "cyclic" albuminuria, in diabetes,† in passive congestions, and in toneless states of the arteries.

with ferratin as well as with supra-renal tincture (m̄xv. ter die post cib.).

* The constriction of the arterial muscularis induced by the supra-renal extract was in all the experiments so pronounced and decisive, as even to suggest the possible use of it as a hæmostatic agent; as, for example, in purpura hæmorrhagica, hæmophilia, hæmoptysis, hæmatemesis, metrorrhagia, &c.

† "A vaso-motor paralysis implicating only the vessels of the chylo-poietic viscera may stand at the foundation of the form of diabetes limited to defective assimilation of ingested carbo-hydrates."—*The Physiology of the Carbo-hydrates*, by F. W. Pavy, M.D., LL.D., F.R.S., &c., 1894, p. 263.

PART II.
PULSE-PRESSURE.

PART II.

PULSE-PRESSURE.

CHAPTER I.

THE MODE OF OBSERVATION.

1. *The Writer's Pulse-pressure Gauge.*

IN order to render more definite and registrable the tactile sense of pulse-pressure, and to provide, moreover, a visible amplification of the pulsatile movements of the arterial wall, so as to league the sense of sight with that of touch in estimating the qualities of the pulse, I have for the past few years employed a small instrument which I have called a "pulse-pressure gauge." It is of portable size; namely, three inches in length (inclusive of the pad and support), two inches in width, and a little more than half an inch

in thickness (fig. 6). A scale, indicating pressures in grammes, extends twice round the two-inch dial. Projecting from the lower part of the box are two rods, of

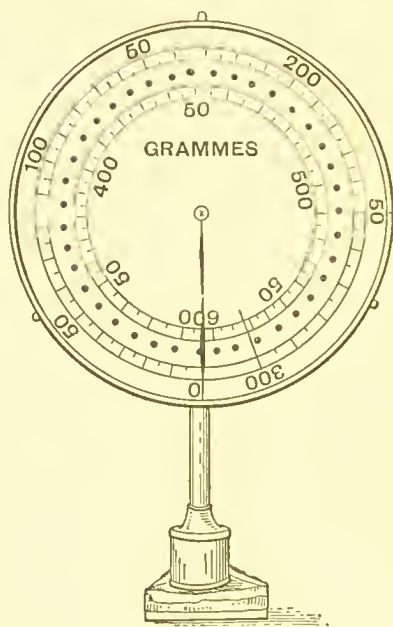


FIG. 6.—The pulse-pressure gauge.*

which the one in front carries the pad to to be adjusted over the pulse; and the

* The foot-rest as now adopted is not correctly indicated by this figure.

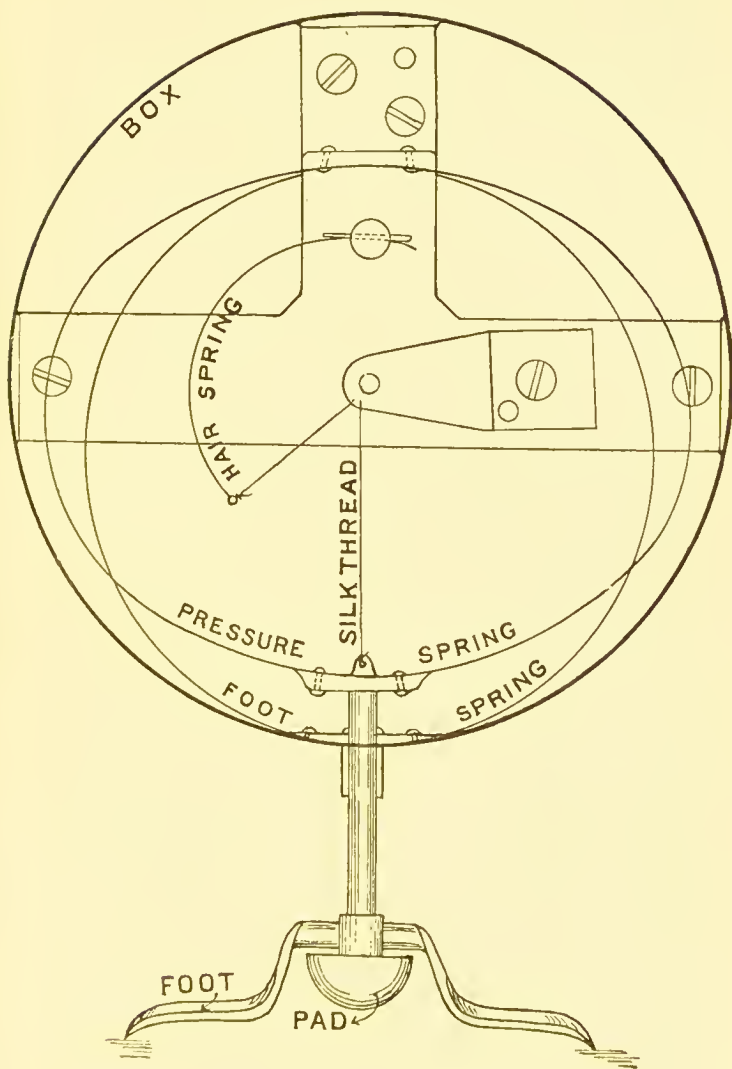


FIG. 7.—Section of pulse-pressure gauge.

other terminates in a foot-rest. Fig. 7 shows the internal mechanism. It is arranged on the same lines as those of the arteriometer; only a circular spring receives the impact of the pulsations, and ensures the registration of the varying degrees of pressure brought to bear on the artery, and the appearance of the amplified pulsatile motion of the indicator. The rod carrying the pad is attached to the circular spring, which is free in the box, but fixed above. A very fine thread passes from the lower part of the spring round the cylinder of the axle, and is maintained—as in the arteriometer—in a state of tension by a piece of watch hair-spring; so that, when the pad is pressed upwards, or is affected by the pulse, the axle with its attached indicator acquires a corresponding motion; and when the pressure ceases the spring and the indicator resume their former position. The graduation is effected by scoring off on the dial the successive positions of the indicator, determined by gramme weights brought to bear on the spring; and the scale of

pressure presents 120 gradations of five grammes each.*

* The following have been the principal contributors towards our knowledge of clinical pulse-pressure: von Basch (*Zeitschrift f. klin. Med.*, vol. ii., *Wien. med. Wochenschr.*, vol. xxiii., *Berl. klin. Wochenschr.*, vol. xxiv., *Abhandlung über den Sphygmomanometer und seine Verwerthung in der Praxis*, Berlin, 1887), Zadek (*Zeitsch. f. klin. Med.*, vol. ii.), Christeller (*Zeitschrift f. klin. Med.*, vol. iii.), Robinowitz (*Inaugural Dissertation*, 1881), Roy and Adami (*Practitioner*, vol. xlv.), Potain (*Archives de Physiol. normale et pathol.*, 1890), Haushalter and Prantois (*Gaz. Hebd. de Méd.*, 1891). Sphygmometers and sphygmoscopes have been proposed by Hérisson (1834), Busco (1853), Scott Alison (1856), Berti (1857), Poznanski (1868), Handfield Jones (1871), Keyt (1874), Pond (1875), Waldenburg (1877), Stevens (1880), von Basch (1883), Bloch and Verdin (1888), Boccolari (1888), Potain (1889), Roy and Adami (1890), and Batten (1891). All the instruments hitherto suggested, except those of Hérisson and his followers (Scott Alison, Poznanski, Pond, Keyt, Stevens, and some others), of Waldenburg, and of Roy and Adami, recorded the *maximum* or obliterating pulse-pressure only; while those of Hérisson and his following registered merely the pressure which induced the fullest development of the pulsations (the *minimum* pressure, see p. 101). Roy and Adami were the first to demonstrate the clinical importance of recording the *minimum* as well as the *maximum* pressure and all intermediate pressures. My pulse-pressure gauge is not constructed on the lines of any of the foregoing instruments.

2. *The Mode of applying the Pulse-pressure Gauge.*

THE patient places the ulnar side of the right forearm on the table. The observer with his left hand extends the hand to an angle of 45 degrees with the forearm, maintaining it in that position throughout the observation, while he keeps his thumb over the radial artery at the flexure of the wrist^{*}; and with the forefinger of the disengaged hand he carefully feels out the position of the artery, and, after testing with his finger-tip, or the blunt end of a pencil, for the best place at which to apply the obliterating pressure (the tip of the right thumb feeling the effects produced on the pulsations and guiding the observer in this preliminary enquiry), he marks the

* When taking the pulse-pressures (minimum and maximum, see p. 101), I am in the habit of keeping the artery blocked by the ball of the thumb, while the tip still perceives the direct pulsations; for, I have found this proceeding advantageous in excluding a reflux beat, in amplifying the movements of the indicator, and in making the reading of the maximum pressure more definite.

selected spot with an aniline point. The pulse-gauge is then applied, held between the forefinger and thumb, or in the concavity between them (fig. 8), while the hand rests on the table to afford in-

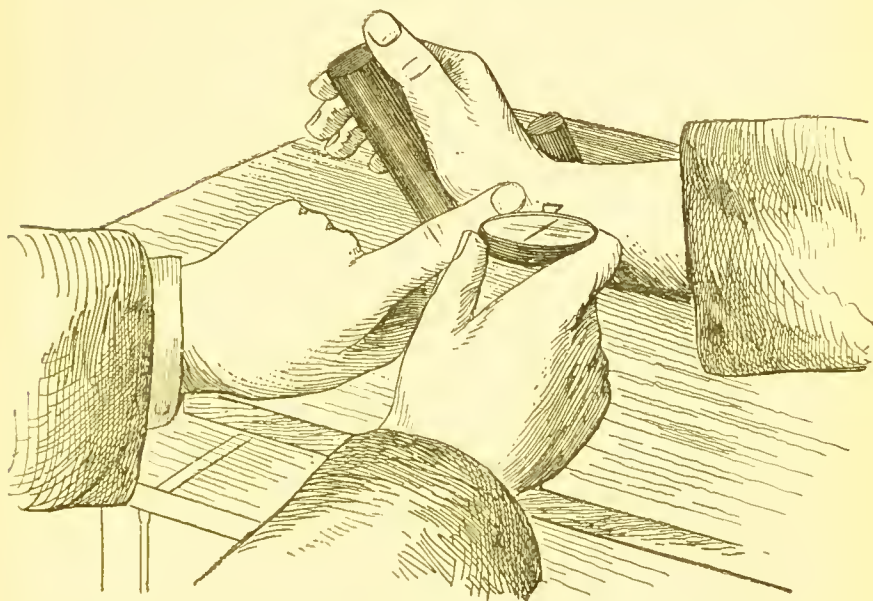


FIG. 8.—The mode of applying the pulse-pressure gauge. A simple wrist-rest (consisting of two rods fixed at suitable angles and positions in a board) is shown.

creased steadiness while applying the required degree of pressure. In order to discover the correct position of the pad, which ought to be perfectly true with the

axis of the artery, the observer should first aim to secure the most ample response of the indicator, and for this purpose it is only necessary to move the pad little by little in the same track, across the axis of the limb, between the tendon of the flexor carpi radialis and the styloid process of the radius; and when the desired position has been found, the left thumb will provide confirmatory evidence, for, after passing the acme of motion, the perception of pulsation will grow *progressively* and *rapidly* smaller untill it vanishes, and will not linger in a minimal degree under increasing pressure, as it will do when the pad occupies an untrue position. Therefore, the proper rule to follow, is to accept only the *lowest obtainable* reading for the obliterating pulse pressure.*

In expert hands the procedure may ap-

* While experimenting with radial arteries through which water was propelled under definite pressures, I observed direct confirmation of this dictum, for the lowest readings could only be obtained when the pad exactly coincided with the centre of the vessel.

pear very easy, but a certain degree of facility can be acquired only by practice—as is indeed the case before any scientific instrument can be employed with satisfaction.

3. *How to determine the Minimum and Maximum Pulse-pressures.**

As is well known, the intra-arterial blood-pressure varies between two extremes; the *maximum*, which is attained during the ventricular systole, and the *minimum*, which is present between the pulsations, or, in other words, during the arterial systole. From the clinical standpoint, it is important to determine the relations which these two pressures bear to each other; for they approximate when the intra-arterial pressure rises, and the interval between them widens when it falls.

The reading of the minimum—or what is sometimes called the mean—pulse-pressure

* I follow the nomenclature adopted by Roy and Adami, *Practitioner*, vol. xlv.

is taken when the indicator attains its maximum oscillation.* At this point the external pressure, having just sufficed to overcome the intra-arterial pressure that persists between the pulsations, the extremity of the pad then completely traverses the internal diameter of the artery,

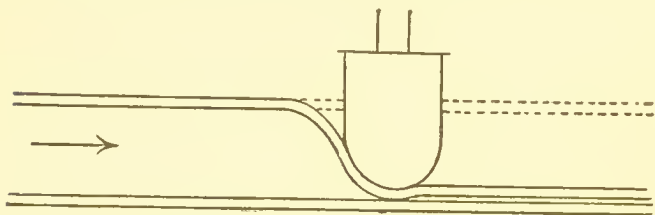


FIG. 9.—The position of the pad in the intervals between the pulsations.

falling in the intervals between the pulsations to the opposite side of the vessel, and being raised a variable distance by the pulsations (fig. 9). The development of motion following the application of pressure to the artery is in proportion to the reduction of the minimum intra-

* A series of equidistant dots, two millimetres apart, on the dial (fig. 6), serves to guide the eye in deciding at what pressure the amplest swing of the indicator takes place, when the volume of the pulse may be measured, and the minimum blood-pressure read off.

arterial pressure, until this is completely overborne, when the pad will make its longest excursion, and in the interval between the beats of the pulse will arrest the flow. The thumb on the artery beyond the pad will generally perceive at the same time a gradual increase of volume in the pulsations, until the point of minimum blood-pressure is being approached; this impression being due to the increasing contrast between the progressive emptying of the vessel with ultimate collapse in the diastolic intervals, and the continued expansion of it when the beats take place. This tactile effect, induced by eliminating the minimum from the maximum blood-pressure by aid of the pulse-gauge, is most pronounced in cases of *plus* tension, and is but slightly apparent in those of *minus* tension. In *plus* tension also the observer will find the widest oscillation of the indicator is maintained over a larger space, and consequently it will require more care to decide exactly where the maximum movement takes place, than in *minus* tension, or even

in moderate tension, in which it is confined within narrow limits. In attempting to read the minimum pulse-pressure, it is best gradually to increase the pressure of the pad until this point is definitely overstepped, and then to reduce it until the widest swing of the indicator is again somewhat lessened ; and finally to narrow the interval by more careful adaptation of pressure. Then the graduation opposite the mean of the interval is taken as the correct reading.

The reading of the maximum pulse-pressure should be determined by the *combined* information provided by the indicator and the tip of the left thumb—the ball of which completely blocks the artery beyond the pad. In all cases the pulsation perceived by the tip of the thumb must of course cease before the reading of the maximum or obliterating pressure can be made. At that point the indicator either becomes quiescent, or still retains a very small degree of movement. In the former case the reading should be taken, but in the latter it should be deferred until the

effect of adding more pressure is ascertained. If then the remnant of motion *is not further diminished*, it is not necessary to read off a higher degree, but if it is reduced, whatever additional pressure it is found necessary to add to the point of securing an irreducible minimum of motion, should be included in the reading.* In all observations the thumb placed on the artery is the best guide to the true position of the pad over the centre of the vessel, the pulsations becoming more and more ample until the minimum pressure is approached, and then quickly diminishing to the vanishing point.

According to my observations with the pulse-gauge, the normal minimum pulse-pressure comes out, as a rule, on attaining two-thirds of the obliterating pressure: for example; it will be 120 grammes when the latter is found to be 180.

* This small margin of motion which cannot be reduced by pressure probably arises generally from a more sudden impact of the pulsations than is present in the cases in which the motion quite definitely ceases.

CHAPTER II.

THE CLINICAL INDICATIONS FURNISHED
BY THE PULSE-PRESSURE GAUGE.I. *The General Clinical Significance of the
Movements of the Indicator.*

THE eye, with a little practice, quickly learns to glean from the movements of the indicator of the pulse-gauge the leading facts in each case respecting the mode and duration of the ventricular contraction, the amount of out-put, the condition of the arterial wall as to contraction or relaxation, the quantity of blood present in the arteries, and the degree of peripheral freedom or resistance; concerning which the unaided finger can form but a comparatively inadequate idea.

The following table epitomises my observations on these points:—

I.—LENGTH OF STROKE:

- | | | |
|---|---|---|
| <i>Before and
after blocking
artery beyond
pad.</i> | { | 1. <i>Small</i> =Small out-put, and small amount of blood in the arteries; arterial constriction; peripheral fulness and arterial reduction; <i>e.g.</i> , atonic gout. |
| | | 2. <i>Large</i> =Large out-put, and plethoric arteries; relaxation of arterial wall; peripheral obstruction and moderate arterial fulness. |
| | | 3. <i>Small, then Large</i> =Free peripheral flow with considerable out-put, as in fever. |
| | | 4. <i>Small, then not enlarged</i> =Arterial narrowing (muscular or organic). |
| | | 5. <i>Large, then much larger</i> =General arterial and peripheral plethora with large out-put; <i>e.g.</i> , plethoric gout. |
| | | 6. <i>Large, then not much enlarged</i> =Peripheral obstruction with <i>plus</i> -tension. |

II.—VELOCITY OF STROKE:

1. *Quick.* (a) *Rise and fall*=Rapid and free ventricular outflow; elasticity of arterial wall (absence of contraction and thickening), and free periphery.
(b) *Fall*=Unusually free flow through periphery; or part of out-put regurgitated.
2. *Slow.* (a) *Rise and fall*=Prolonged and obstructed ventricular flow; reduced arterial elasticity; and obstructed periphery. May be masked for a time by palpitation or fever.
(b) *Fall*=Impeded flow through periphery, with vigorous and prolonged ventricular contraction.

III.—THE TURN:

1. *Sharp* = Normal or quick ventricular contraction.
2. *Slow* = Prolonged or slow ventricular contraction.

IV.—HALT IN THE FALL:—Sudden systole, with abrupt termination of the out-put.

Position of halt in the fall. Middle third = *plus*-tension.

At the bottom (dicrotism)=*low* tension.

2. *The signs of Plus and Minus Arterial Tension furnished by the Pulse-gauge.*

THE tactile qualities of the pulse in the various forms and degrees of arterial tension are translated in an amplified form to the eye by the pulse-gauge.

(a). When radial tension is in excess, the artery is felt to be full with increased resistance to compression; and when it is diminished the vessel becomes soft and comparatively empty. The recognition and estimation of the increased resistance—especially in the slighter forms of *plus* tension—may, however, be readily overlooked when the tactile sense is insufficiently trained; then the full artery of *plus* tension may be indistinguishable from one of merely thickened walls; and I am persuaded that even the well trained finger is not infrequently in some uncertainty on this point.

When the pulse-pressure gauge is applied to a radial of high intra-arterial tension due to increased peripheral resis-

tance, the oscillations of the indicator are comparatively small under the lower pressures, and the maximum motion is sustained over a much wider area than obtains in the normal condition of the artery. Thus the instrument renders to the eye what the finger feels when testing a high tension pulse ; namely, the gradual and somewhat delayed development of the pulsations under steadily increasing compression ; and the undue maintenance of the maximum impulse as the finger further counter-balances the intra-arterial pressure. Moreover, the minimum blood-pressure will, as a rule, be observed to rise into the final third of the obliterating pressure recorded by the instrument ; and during the successive additions to the pressure of the pad, the thumb on the distal side of it at the same time perceives a progressive amplification of the beats (see p. 103).

In reduced intra-arterial tension, the movements of the indicator are comparatively large under the lower pressures, and they pretty sharply attain their maximum

development—indicating the minimum blood-pressure—in the middle third of the record of the obliterating pressure, and the thumb does not feel an increased impact of the pulsations during the observation. In judging of the amount of intra-arterial tension, it is, as a rule, more useful to observe the way in which the movements of the indicator are affected by the progressive application of pressure, than to ascertain the degrees of external resistance that counter-balance the minimum and maximum blood-pressures; for these may be comparatively low, while the indicator may point to the existence of arterial tension, which may be, moreover, supported by corroborative clinical facts. In this way the pulse pressure-gauge amplifies the tactile sense, and in applying it, it is as easy to vary with exactitude the degrees of pressure, and to observe the effect of them on the volume of the pulsations, as it is to use the finger with the view of estimating the variations of intra-arterial resistance.

(b). When the arterial tonus and blood-

pressure are normal, the sudden arrest of the flow through the artery causes a considerable increase in the volume of the pulsations on the proximal side of the block, and, as a rule, the cessation of them on the distal side. The amplification of the pulsations consequent on stopping the circulation may be conveniently denominated "the expansile reaction." It is best observed by extending the hand of the patient to about 45° on the fore-arm, and by applying two fingertips *not too* firmly over the artery, and while the current is being arrested beyond them, maintaining throughout the observation the same degree of light or moderate pressure. When the flow of blood is suddenly stopped, it would seem that the momentum produced by intercepting the onflow of the blood dilates the portion of the artery immediately on the proximal side of the point of arrest (fig. 10), and is in this way made available for testing the expansibility of the arterial wall. The observer soon learns by experience what is the normal degree of the "expansile re-

action" in health. According to my observation it varies very considerably in the different physiological conditions of the circulation, the variations being temporary, and due to the increase or diminution of the muscular contractility of the arterial wall—increased contraction diminishing or annulling, while relaxation increases the bulging. The influence of the muscular element in modifying this reaction is readily shown by testing the condition of the radial artery immediately after immersing the arm in cold and hot water. In the former case, the arterial expansion will either fail to be apparent, or will be but slight; while in the latter it will be greatly amplified (fig. 11). I have observed, on testing this matter with the pulse-gauge, that the radial expansibility of 50 per cent. may be reduced below 25 per cent. by cold, and may be increased over 100 per cent. by hot immersion—local or general bath (figs. 11, 12). It is similarly affected by the temperature of the atmosphere (figs. 13, 14, 15), and it is increased by exercise (figs.

16, 17), by the absorptive stage of digestion (fig. 18), by sleep and by recumbency (figs. 15, 19), as compared with that observed in the sitting and standing postures (figs. 13, 14).

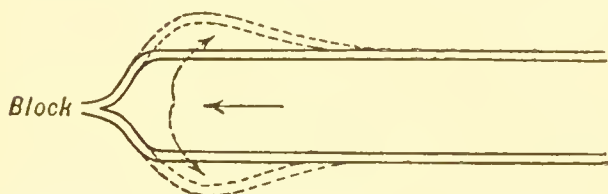
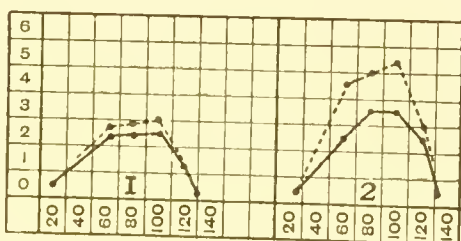


FIG. 10.—The expansile reaction.



* FIG. 11.—Recumbent. Immersion of forearm in :—
 (1) *Cold water*—calibre, 1.5 mm.; reflux beat absent.
 (2) *Hot water*—calibre, 2.5 mm.; reflux beat, 3 mm.

* The diagrams (11 to 19) present a curve constructed out of the measurements of the recorded movements of the indicator under the progressive degrees of pressure applied to the artery, the measurements being expressed in mm. on the left side of the tables, and the pressure in grammes at the foot. The continuous line indicates the movements produced by the unchecked

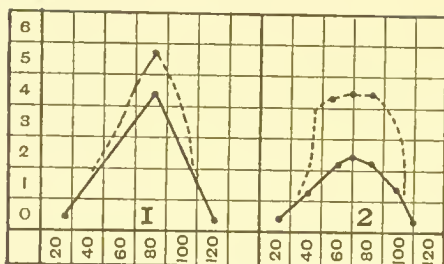


FIG. 12.—Recumbent. Hot bath (temperature 101° F.).

(1) *Before bath*—calibre, 2.5 mm.; reflux beat, 2 mm.

(2) *In bath ten minutes*—calibre, 1.5; reflux beat, 2 mm.

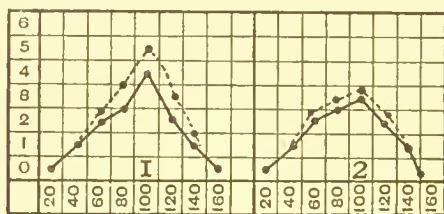


FIG. 13.—Standing.

(1) Temperature in shade, 61.6° F.; calibre, 2.5 mm.; reflux beat, 2 mm.

(2) Temperature in shade, 43° F.; calibre, 2 mm.; reflux beat absent.

flow through the artery; and the interrupted line shows the increased amplitude of them caused by intercepting the current beyond the pad of the instrument. Each diagram represents an actual observation, and is a fair example of the average of a number of observations made on the same subject under the same physiological conditions.

In the clinical field I have observed that when the arterial tension is low, the

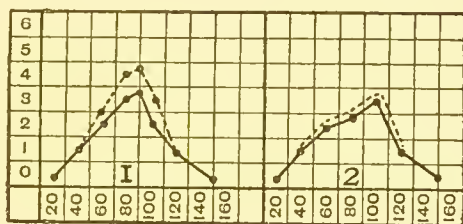


FIG. 14.—Sitting.

- (1) Temperature in shade, 61.6° F.; calibre, 2 mm.; reflux beat, 1 mm.
 (2) Temperature in shade, 43° F.; calibre, 1.5 mm.; reflux beat, trace.

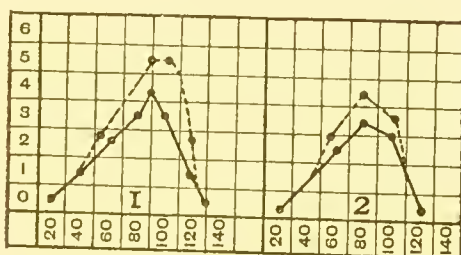


FIG. 15.—Recumbent.

- (1) Temperature in shade, 61.6° F.; calibre, 1.5 mm.; reflux beat, .5 mm.
 (2) Temperature in shade, 43° F.; calibre, 1 mm.; reflux beat absent.

movements of the indicator are greatly amplified by blocking the artery beyond

the pad—they may even be doubled; but when the tension is high, the augmentation is but slight, or may fail to become

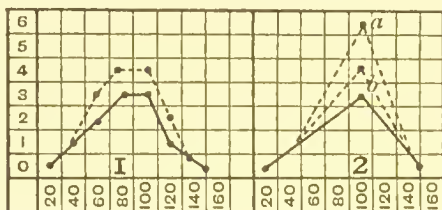


FIG. 16.—Exercise (ascending). Standing.

- (1) *Before walk*—calibre, 3 mm.; reflux beat, 3 mm.
 (2) (a) *Immediately after climbing half an hour*—calibre, 1.5 mm.; reflux beat absent.
 (b) *After resting five minutes*—calibre, 1.5 mm.; reflux beat, 1 mm.

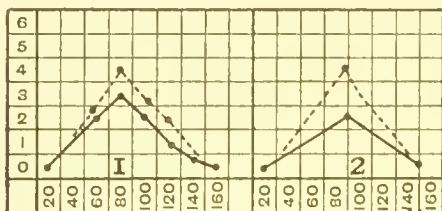


FIG. 17.—Exercise (level). Sitting.

- (1) *Before walk*—calibre, 2 mm.; reflux beat, 3 mm.
 (2) *After one hour's walk*—calibre, 1.5; reflux beat absent.

manifest. It has seemed to me, that the leading causes which prevent the appearance of the normal development of the

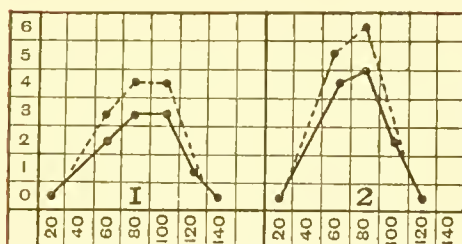
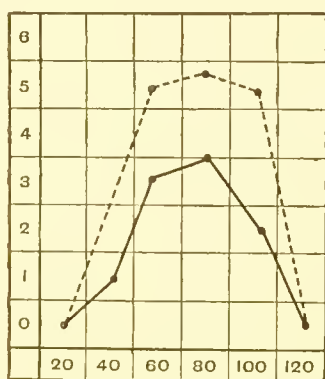


FIG. 18.—Two hours after breakfast.

- (1) *Standing*—calibre, 3 mm.; reflux beat, 3 mm.
 (2) *Recumbent*—calibre, 2 mm.; reflux beat, 2 mm.

FIG 19.—Recumbent. Sleep.
Reflux beat absent.

expansile reaction are (1) vaso-motor constriction, and (2) distension attaining to or approaching the maximum stretching limit of the arterial wall; while those that amplify it are (1) vaso-motor relaxation,

and (2) reduction of intra-arterial pressure.

(c) It has been taught by Dr. Douglas Powell, that in high arterial tension the pulsations persist beyond the point of arrest of the onward flow—there being, what has been termed, a reflux beat, derived from an abnormally patulous condition of the inosculations between the radial and ulnar arteries.* I have observed that this distal pulsation may be temporarily developed under strictly physiological conditions; as in the absorptive stage of digestion an hour or two after meals (fig. 18), and as a result of warmth (figs. 11, 12, 13, 14, 15); and when present in the sitting and standing postures (figs. 13, 14), it will in health disappear in recumbency (fig. 15), during exercise (figs. 16, 17), and on exposure to cold (figs. 11, 13, 14, 15).

* The *ramus superficialis volæ* (which, though not visibly or palpably enlarged, may be felt pulsating on the inner border of the ball of the thumb) is, as a rule, the channel of the reflux beat: for, when the flow through this vessel is obliterated by pressure, the distal pulsation usually ceases.

To be of value as a clinical sign the reflux beat should not be transitory, as it is apt to be in health, but permanent, and it should be present in all the postures, and especially in recumbency. I have observed that in asthenic cases, it is, as a rule, absent in the sitting and standing postures, but becomes apparent and even pronounced in recumbency, when at the same time the radial calibre attains its maximum measurement (see pp. 32, 33).

The clinical significance of the reflux beat in regard to *plus* tension mainly rests in the fact, that it is usually permanent and well developed in all the postures, when the arterial blood-pressure is raised from increased resistance confined to the peripheric vessels only, and is, as a rule, absent—at least in the sitting and standing postures—in that form of high tension caused by constriction involving the small and medium-sized arteries (including the radial).

In order to show the absence or the presence—and when present the ampli-

tude—of the reflux beat by means of the pulse-gauge, it is merely necessary to arrest the onward flow through the artery while the instrument is *in situ*.

I will briefly epitomize the radial signs of *plus* and *minus* tension afforded by the pulse-pressure gauge and the arteriometer.

(a). *Plus-tension*.

1. LATE development of the maximum oscillations of the indicator, which are maintained over a wide area on the dial, and encroach on the final third of the obliterating pressure.

2. The rise, fall, and turn of the stroke are apt to lose their normal sharpness, and a halt may appear in the middle of the fall (see p. 107).

3. An increase of the pulsations felt by the examining finger beyond the pad of the pulse-gauge or the arteriometer, as the artery is being gradually compressed.

4. Expansile reaction reduced or abol-

ished, especially in asthenic or constrictive tension—in the less complete forms of which it generally reappears or develops in recumbency.

5. Reflux beat permanent and in all the postures. In asthenic tension it may develop in recumbency.

6. The calibre uniform in the postures, increased in peripherally induced tension, and reduced in the constrictive form. In asthenic tension the contracted calibre of the sitting and standing postures enlarges in recumbency.

7. High pressures (minimum and obliterating) in peripherally induced tension (see p. 129).

(b). *Minus-tension.*

1. EARLY development of the maximum movements of the indicator, which are sharply attained and passed in the middle third of the obliterating pressure.

2. The rise, fall, and turn of the stroke are quick, and a halt is apt to appear at

the bottom of the fall—dichrotism (see p. 107).

3. Expansile reaction increased.
4. Postural variations of the calibre are well marked.

CHAPTER III.

THE RADIAL PULSE-PRESSURE: NORMAL
AND ABNORMAL.1. *Difficulties and Fallacies.*

THE determination of the blood-pressure in man must always be merely approximate; for it can only be taken through the intervention of tissues, that vary in resistance in different individuals. Anything like uniform and absolute accuracy cannot possibly be attained. Taking, however, the general run of patients, I do not think that that resistance is quite so variable as to impair the practical character of this mode of observation. The finger can pretty readily detect exceptionally high tissue-resistance—so that, when it is apparent, observation may be made under qualification, or it should not be

attempted.* Some experiments with excised arteries show, that the resistance offered by the arterial wall, even when thickened by atheroma, is much less than anyone would *primâ facie* suppose it to be. For example, on allowing water to run through two radials, one with soft walls scarcely 0.5 mm. in thickness derived from a woman æt. 22, and the other with walls 0.75 mm. in thickness derived from a man æt. 72, occlusion was effected in both cases by the pressure of $2\frac{1}{2}$ grammes. A radial artery distinctly hard and calcareous, would, of course, offer increased resistance; but that is a condition readily detected by the finger, and may in some

* In using the pulse-pressure gauge an approximate estimate of the amount of resistance offered by the superposed tissues may be obtained by observing when the indicator begins to pulsate. As a rule it does so at once, or before the pressure attains twenty grammes, while in cases of increased tissue-resistance, it fails to do so until the pressure has been advanced to fifty, sixty, or more grammes. A correction may, therefore, be made in these exceptional instances, by deducting from the readings the motionless interval beyond twenty grammes, which suffices to cover the tissue-resistance met with in the general run of patients.

degree be allowed for. A palpable thickening of the arterial wall short of calcification, therefore, offers but a trifling resistance to closure of the artery. As I have previously pointed out (pp. 9, 10) a certain proportion of cases is rendered unsuitable for any instrumental observation of the pulse, in consequence of anatomical departures, &c.

2. *The tactile appreciation of Pulse-pressures.*

PERHAPS the best illustration of the somewhat feeble discriminative power of even the educated tactile sense, in estimating the degrees of intra-arterial pressure, is afforded by propelling water intermittently through a piece of artery in communication with a mercurial manometer, the observer placing his finger over it and closing his eyes, and declaring the tactile readings of the various pressures, while an assistant compares them with the true record of the manometer. The discrepancies which thus become manifest—

amounting to fifty or more mm. of mercury—tell their own tale. The finger, invaluable though it be in clinical observation of the qualities of the pulse, does not, therefore, possess a highly refined sense of resistance for the purpose of determining the variations of the pulse-pressure. Each observer, moreover, acquires his own incommunicable idea of the limits of the standard of normal radial resistance; and I think it is not improbable, that many observers are apt to pitch it somewhat too high. Observations with the pulse-pressure gauge has shown that when other indications are favourable, the lower ranges of pressure are not only more salutary, but are very often compatible with the highest health.

3. *The average Pulse-pressures. Normal Pulse-pressures.*

A PRETTY large experience with the pulse-pressure gauge enables me to conclude that the normal obliterating pulse-pres-

sure, as a rule, falls within the following limits—in men from 140 to 200, and in women from 120 to 160 grammes. I have already pointed out, that the average minimum pressure is one-third less than the maximum (see p. 105). Unless the finger detects an abnormally high tissue-resistance, I should regard, as a rule, a higher maximum pressure than 200 grammes in women, or 250 in men of average build as within the range of excessive pulse-pressure. Therefore, if it is found necessary to press the indicator into the second circle before the pulsations are obliterated, the pulse-resistance should be regarded as decidedly high.*

* In order to decide whether any particular observation indicates a fairly normal pulse-pressure, or one above the average—for this is the aspect which is of special clinical importance—it is necessary to take into consideration certain qualifying conditions, such as the age, sex, build and general nutritive condition of the individual. As a rule, the normal pressure is higher in big broad-built men and women, especially when sanguineous and obese, and lower in the small and thin; and whenever it rises, even slightly, above the maximum physiological limit of the individual, the calibre becomes uniform.

4. *Abnormal Pulse-pressure.*

THE radial artery, occupying an intermediate position between the centre and the periphery of the circulation, is a convenient site for the study of the variations of the average pressure within the arterial system; but it fails to furnish much, if any, direct evidence of increased blood-pressure in that form of *plus* tension, in which the radial and even the arteries of larger size are involved in vaso-motor contraction; for then the area of increased peripheral resistance includes the radial itself, and the pulse becomes small and weak, and the pulse-pressure gauge affords low readings—even though there may be undoubted evidence of increased blood-pressure in the central arteries.* The radial is, however, an important avenue of direct observation of the blood-pressure

* The asthenic form of arterial tension here referred to is of frequent occurrence in anæmia, neurasthenia, hysteria, hypochondriasis, atonic gout—especially in women—asthenia in many other forms, and especially associated with some source of irritation, &c. (see p. 33).

in the other leading variety of *plus* tension, in which the increased resistance is limited to the terminal arteries, or to the capillaries, as in lithiasis, contracting kidney, &c. In my observation of cases of this type I have found my pulse-pressure gauge of service in enabling me to definitely recognize the less palpable increments of *plus* pressure—especially when the finger afforded somewhat equivocal evidence—and to determine the degrees of pressure with more precision than could be defined by the finger. These practical advantages will not be regarded as inconsiderable, when it is recognised, how amenable to treatment are the minor degrees of *plus* tension, and how these, when disregarded, are apt to gradually and imperceptibly lead on to very serious evils that shorten life—such as irretrievable arterial and cardiac disease.* It is un-

* The peripheral origin of heart disease, &c., is a matter of considerable clinical interest. It is, however, beside the purpose of this little book to detail the centric and other effects of *plus* tension. This aspect of the subject is well delineated in Sir William Broadbent's excellent book on *The Pulse*.

doubtedly an advantage to be able to detect the earliest drifting in this direction. Moreover, I have found this mode of observation useful in tracking and recording the effects of the treatment of high tension, which in these days has acquired an important position in practical therapeutics (see p. 132): and it has occasionally reflected a suggestive influence on diagnosis; for now and then a persistent record of an exceptionally high pulse-pressure has prompted me to the belief, that there was a granular kidney maintaining the otherwise unaccountable tension, and careful enquiry has at times established the fact. I have, however, observed similar high readings—such as from 350 to 500 grammes—when no evidence of insidious renal disease could be ascertained; but, whether such disease existed or not, the persistence of excessive intra-arterial pressure made me alive to the not improbable occurrence sooner or later of cerebral hæmorrhage; and in several such cases this event has unhappily supervened (see p. 148), while in others the comparative

frequency of death from apoplexy in near relatives seemed to point to a hereditary disposition to high arterial tension of this type.

CHAPTER IV.

THE PULSE-PRESSURE GAUGE AND ARTERIOMETER AS AIDS IN DETERMINING THE EFFECTS OF THE TREATMENT OF PLUS ARTERIAL TENSION.

I WILL briefly illustrate how the pulse-gauge and the arteriometer may enable the observer to follow the results of the treatment of *plus* tension ; and for this purpose I will select the modifying influence of recumbency, diet, mineral water and baths, and vaso-motor relaxants.

I. *Recumbency.*

THE reduction of the muscular contractility of the arterial wall in recumbency (as shown by the pronounced increase of the expansile reaction in that posture) shows that a much deeper physiological significance should be attached to it, than it possesses in the conventional sense ; for the rest

extends in a great measure to the plain involuntary as well as to the voluntary muscles. Hence the particular value of recumbent rest whenever the walls of the arteries are in a state of tonic constriction, as in the asthenic forms of *plus* tension. A typical illustration of this position is afforded by anæmia. In this condition the arteries are reduced in calibre by contraction in the sitting, and still more so in the standing posture, and they become enlarged in recumbency when the contraction subsides. Hence in the sitting and standing postures a heartward strain is induced by the contraction, which passes away on the assumption of recumbent rest. In keeping with this fact is the frequency of ventricular dilatation in anæmic subjects,* and the freedom from this cardiac complication when they maintain the recumbent posture.† There is, moreover, a

* *On the Condition of the Vascular System in Anæmic Debility*, by Arthur Foxwell, M.D., "British Medical Journal," vol. i., 1892, p. 799.

† *Anæmia as a Cause of Permanent Heart Lesion*, by Henry Halford, M.D., "British Medical Journal," vol. i., 1892, p. 853.

satisfactory physiological explanation why the ventricle becomes dilated when the intra-aortic pressure rises. Professors Roy and Adami have shown, that "the ventricles normally do not become completely emptied at the end of systole. If the pressure in the aorta fall without any change in the force of the contractions of the ventricular wall, the ventricle empties itself more completely at each beat, and there is less residual blood. If, on the other hand, the aortic pressure rise, let us say from 80 to 160 mm. of Hg, which is within the normal limits in man or the dog, the resistance offered to each contraction will be doubled. The increased aortic pressure will necessarily produce the same effect on the ventricular wall, which would result from doubling the weight on a parallel-fibred voluntary muscle, which is being stimulated to a series of maximal contractions by single induction shocks, care being taken to prevent the muscle being stretched by the weight when in a relaxed condition. In both cases the shortening in full con-

traction will be diminished.....With *increase of aortic pressure there is, other things being equal, an increase in the amount of residual blood.....*The increase of residual blood is, of course, always increased, also, whenever the aortic pressure remaining constant, the force of the ventricular contractions is reduced from mal-nutrition or other cause.”*

In view of these physiological facts it is not surprising to find that dilatation of the ventricles is not uncommon in anæmic subjects, and that it may be avoided by enjoining recumbent rest. In anæmia the advantages of recumbency as a therapeutic measure are further emphasized by the arteriometer having demonstrated, that from 25 to 100 per cent. more blood is discharged into the tissues in the recumbent than obtains in the sitting posture. According to my observation the radial

* *Contributions to the Physiology and Pathology of the Mammalian Heart*, by C. S. Roy, F.R.S., M.D., Professor of Pathology, Cambridge, and J. G. Adami, M.D., M.A., Fellow of Jesus College, Cambridge (from the Cambridge Pathological Laboratory), “Phil. Trans. of R. S. of London,” vol. 183 (1892), pp. 212 and 213.

calibres of the standing and sitting postures increase in recumbency, as a rule, in proportion to the severity of the anæmia, and to the need of recumbent rest. At present I am disposed to adopt the following as a good working rule: when the sitting radial calibre enlarges 100 per cent. *e.g.*, 1·0 mm. becoming 2·0 mm. in recumbency, the rest should be absolute for a time; but when the rise falls short of this decisive one, it may suffice merely to alternate recumbency with passive or active exercise. The following radial measurements illustrate the application of this rule, and the prescription of the chalybeate waters of Harrogate and of other suitable treatment.

					RADIAL CALIBRE. mm.		RADIAL CALIBRE. mm.
Mrs. C., æt. 56.	R.	...	...	...	1·7	} in 14 days	1·6
	S.	...	...	...	0·6		1·7
	St.	...	...	...	0·5		1·8
Miss L., æt. 20.	R.	...	...	...	1·7	} in 23 days	1·5
	S.	...	...	...	1·0		1·7
	St.	...	...	...	1 1		1·2

Miss E., æt. 42.	R.	...	...	2'0	} in 21 days	1'5
	S.	...	...	1'4		1'8
	St.	...	...	0'9		1'6
Miss D., æt. 24.	R.	...	...	1'6	} in 30 days	1'3
	S.	...	...	1'2		1'7
Mrs. W., æt. 32.	R.	...	...	1'9	} in 22 days	1'4
	S.	...	...	1'1		1'8
	St.	...	...	0'8		1'2
Miss T., æt. 23.	R.	...	...	2'3	} in 21 days	1'7
	S.	...	...	1'5		2'0
	St.	...	...	1'2		1'8
Mrs. B., æt. 56.	R.	...	...	2'4	} in 9 days	1'9
	S.	...	...	1'3		2'0
Miss C., æt. 18.	R.	...	...	1'7	} in 24 days	1'5
	S.	...	...	1'1		1'9
Mrs. C., æt. 31.	R.	...	...	2'1	} in 16 days	1'9
	S.	...	...	1'6		2'4
Miss S., æt. 22.	R.	...	...	2'3	} in 19 days	1'7
	S.	...	...	1'5		2'0
	St.	...	...	1'3		1'8

The adoption of recumbency is beneficial in other forms of asthenic arterial tension.

		RADIAL CALIBRE.		RADIAL CALIBRE.	
		mm.		mm.	
Mr. B., æt. 60. Neurasthenia.	R.	...	1'8	} in 31 days	1'5
	S.	...	0'9		1'9
	St.	...	0'6		1'8

Mrs. L., æt. 53.	R.	...	...	2'4	} in 29 days {	1'5
Neurasthenia.	S.	...	...	1'0		2'1
	St.	...	...	0'9		2'0
Miss E., æt. 36.	R.	...	...	1'9	} in 24 days {	1'4
Asthenic dyspepsia.	S.	...	...	1'2		1'9
Mrs. S., æt. 38	R.	...	...	1'8	} in 37 days {	1'5
General asthenia.	S.	...	...	1'3		1'9
	St.	...	...	1'0		1'7
Mrs. T., æt. 48.	R.	...	...	1'9	} in 13 days {	1'7
Asthenia.	S.	...	...	1'5		2'1
Mrs. S., æt. 70.	R.	...	...	1'7	} in 14 days {	1'5
Asthenia.	S.	...	...	1'0		2'0
Mrs. K., æt. 62.	R.	...	...	2'0	} in 32 days {	1'8
Neurasthenia. Insomnia.	S.	...	...	1'3		2'3
Mrs. E., æt. 53.	R.	...	...	2'4	} in 38 days {	1'9
Neurasthenia. Insomnia.	S.	...	...	1.6		2'4
Miss R., æt. 61.	R.	...	...	1'7	} in 30 days {	1'8
Asthenia.	S.	...	...	1'0		2'3

Though constriction of the arterial wall is the predominant condition in this form of plus tension—especially in the active postures—my observations have shown, that in a minor degree it is very frequently present when the radial blood-pressure is raised by increased resistance mainly confined to the capillaries and the

terminal arteries; for, when the blood-pressure falls as the result of treatment, the radial calibre not infrequently increases (see pp. 141-2).^{*} Here again recumbency is often of considerable therapeutic value as an auxiliary to other measures adopted to modify the excessive blood-pressure; and it is particularly so in that modified form of *plus* tension, which is frequently met with in elderly subjects—especially when of gouty habit—in whom the radial pressures, though not much, if at all, in excess of the normal range, are relatively high in view of the asthenic condition. My radial observations have clearly demonstrated, that recumbent rest

* It may be thought that the readings furnished by an instrument like the pulse-pressure gauge, provided with a *solid* pad, should be qualified by a correction for the diameter of the artery—a given intra-arterial pressure becoming greater or less as the calibre of the vessel increases or diminishes. I have not yet submitted this matter to the test of experiment; for so far, I have been satisfied with the direct readings of the instrument, which has proved itself capable of determining a marked reduction as well as a pronounced rise (see p. 53) of the blood-pressure, when in the same individual the calibre increased or diminished.

is most useful in the management of all forms of *plus* tension, especially when prescribed during the periods of accession which are apt to supervene every now and then.

2. *Diet.*

It is now well recognised that *plus* tension of peripheric origin (gout, renal disease) may be considerably modified by dietetic directions. The following is a good illustration of what may be done in this way. In 1892 I saw a gentleman, æt. 57, suffering from granular kidney, and presenting the typical symptoms of that disease. The maximum radial pressure varied from 400 to 450 grammes. A diet of milk, farinacea, vegetables, and white meats (chicken and white fish) was prescribed. Last year I found the obliterating pulse-pressure reduced to from 170 to 230 grammes; and the patient's weight had increased from 11 st. 5 lb. to 12 st. 2 lb.*

* This autumn I observed the same favourable condition of the pulse-pressure and of the body-weight.

This case clearly showed that the high arterial tension of granular kidney may be markedly reduced by diet alone, while the general health is well maintained—and certainly does not suffer deterioration in consequence of the reduction of the excessive blood-pressure.

3. *Mineral Waters and Baths.*

HYDRO-THERAPEUTICS is of undoubted value in the treatment of *plus* tension, especially when caused by gout. As my experience in this direction is mainly based on observation of the effects of the Harrogate waters (sulphuretted and fer-ruginous salines) I will quote from my notes a few examples of gouty arterial tension treated by them.

		RADIAL CALIBRE.		MAXIMUM PULSE- PRESSURE.				RADIAL CALIBRE.		MAXIMUM PULSE- PRESSURE.	
		mm.		Grammes.				mm.		Grammes.	
Col. S., æt. 54.	R. ...	1'9	...	260	}	in 19 days	{	1'5	...	160	
	S. ...	1'9	...					2'1	...		
	St. ...	1'9	...					2'2	...		

Adm. C., æt. 73.	R. ... 1'9 ...	} in 21 days	{ 1'4 ...
	S. ... 1 9 ... 250		{ 1'9 ... 170
Col. L., æt. 60.	R. ... 1'9 ...	} in 42 days	{ 1'7 ...
	S. ... 1'9 .. 300		{ 2'1 ... 210
	St. ... 1.9 ...		{ 2'3 ...
Mrs. S., æt. 48.	R. ... 1'6 ...	} in 35 days	{ 1'5 ...
	S. ... 1'6 ... 330		{ 1'9 ... 230
Miss N., æt. 49.	R. ... 1'5 ...	} in 21 days	{ 1'5 ...
	S. ... 1'5 ... 300		{ 2'0 ... 210
	St. ... 1'5 ...		{ 1'9 ...
Mr. M., æt. 43.	R. ... 2'0 ...	} in 23 days	{ 1'6 ...
	S. ... 2'0 ... 250		{ 2'0 ... 190
Mrs. M., æt. 70.	R. ... 1'7 ...	} in 18 days	{ 1'8 ...
	S. ... 1'7 ... 300		{ 2'1 ... 210
Mr. C., æt. 50.	R. ... 2'0 ...	} in 16 days	{ 1'9 ...
	S. ... 2'0 ... 260		{ 2'5 ... 180
Miss B., æt. 32.	R. ... 1'2 ...	} in 6 weeks	{ 1'6 ...
	S. ... 1'2 ... 300		{ 1'9 ... 200
Mr. A., æt. 50.	R. ... 2'3 ...	} in 13 days	{ 2'1 ...
	S. ... 2'3 ... 300		{ 2'6 ... 250

I have observed, that bathing alone may effectually reduce *plus* tension; and the form of it which I have found to exert the most potent influence in this direction is the Harrogate modification of the Aix-Bains douche. In illustration of this

fact I will merely quote an example or two from a large number of similar records; and I select the following, because the age of the subjects might have warranted the conclusion that the radial calibre had already become fixed from the development of physiological arterio-fibrosis. The massage-douche, however, was sufficiently effective in liberating the arterial wall and in reducing the arterial tension, that the physiological postural variations gradually appeared and were fully restored within three weeks.

		RADIAL CALIBRE.		MAXIMUM PULSE- PRESSURE.				RADIAL CALIBRE.		MAXIMUM PULSE- PRESSURE.	
		mm.		Grammes.				mm.		Grammes.	
Mrs. M., æt. 70.	R.	...	1·7	...		} in 18 days	{	1·8	...		
	S.	...	1·7	...	300			2·1	...	210	
Col. K., æt. 68.	R.	...	2·0	...		} in 21 days	{	2·0	...		
	S.	...	2·0	...	180			2·4	...	150	
Mr. Mo., æt. 71.	R.	...	1·9	...		} in 17 days	{	1·8	...		
	S.	...	1·9	...				2·2	...		

* These radial observations were, as a rule, made on bath-free days. The records intervening between the first and the last present confirmatory transitional readings.

The following examples show, that when the purgative waters reduce the arterial tension but slightly, and induce only limited postural variations of the calibre, the massage-douche may develop these effects more fully.

	MINERAL WATERS ALONE.		MASSAGE-DOUCHE IN ADDITION.	
Mr. K., æt. 54.				
Radial calibre	{ R. 2'5 S. 2'5 }	in 10 days	{ 2'1 2'3 }	in 7 days
Maximum pulse- pressure	320		250	
Mrs. P., æt. 46.				
Radial calibre	{ R. 1'5 S. 1'5 }	in 4 days	{ 1'6 1'7 }	in 5 days
Maximum pulse- pressure	170		160	in 11 days

In all the cases in which the postural variations of the radial calibre were restored the general health was manifestly improved; as shown by gain in weight, or by increased vigour and power of resistance, or by the return of elasticity of mind and body.*

* Inasmuch as increased peripheral resistance may determine dilatation of the cardiac chambers (see pp. 129, 133-5), a reduction of that resistance by means

4. *Vaso-motor Relaxants.*

From the physiological standpoint, it would seem that the interesting group of remedies, of which nitroglycerine and the nitrites of amyl and of sodium are the representative members, should prove of service in the treatment of certain forms of peripheral resistance that induce *plus* tension; and in many cases that therapeutic forecast has been amply verified—especially in the amelioration of the accessions of tension,

of baths, massage, &c., when the cardiac muscle is over-taxed by it, will doubtless favour the unloading of the ventricles, and will thus lessen the amount of residual blood and the dilatation. Dr. Theodor Schott (in Bad Nauheim) has demonstrated this effect of baths, and has illustrated it by diagrams, showing the extent to which he had observed the reduction of the cardiac dulness, and the forward advance of the apex beat (see “*Deutsche Medizinal-Zeitung*,” 1888 and 1890; “*Zur Pathologie und Therapie der Angina Pectoris*,” and “*Neurasthenie und Herzkrankheiten*”). Harrogate affords every facility for the application of this mode of treatment of cardiac dilatation; especially too, as Dr. Theodor Schott’s method of passive resistive gymnastics, applied with much success at Nauheim, is now available there.

which are apt to supervene during the course of the cases of this type. The relaxant effects of these remedies on the arterial wall may be followed by the arteriometer and the pulse pressure-gauge. I have observed, when the radial presents an uniform calibre in posture—as in angina pectoris, &c.—that nitroglycerine may induce postural variation and reduce the blood-pressure. The following is a good illustration of this fact.

1893.

Mr. G., æt. 61.	...	...	Radial calibres...	...	S. 20 mm.
Liver derangement	...	...	...	...	R. 1'5 "
No angina pectoris			<i>Obliterating pulse-pressure</i>	...	180 grammes.

1894.

Angina pectoris	{	...	Radial calibres	...	S. 2'0 mm.
					R. 2'0 "
			<i>Obliterating pulse-pressure</i>	...	300 grammes.
Nitro-glycerine Gr. $\frac{1}{100}$ <i>ter die</i>	{	...	Radial calibres	...	S. 1'9 mm.
		...	...	...	R. 2'2 "
			<i>Obliterating pulse-pressure</i>	...	220 grammes.
The same dose every night for 14 weeks	{	...	Radial calibres	...	S. 2'0 mm.
		...	...	...	R. 1'6 "
			<i>Obliterating pulse-pressure</i>	...	220 grammes.

When twelve months ago the patient came under observation for liver derangement, there were no signs of angina pectoris or of *plus* tension; and the arteries

responded normally to posture. Now he reappears with angina pectoris, *plus* tension, and the absence of postural variations; and under small doses of nitroglycerine the pulse-pressure falls, the calibre varies with posture, and the attacks of anginal pain diminish.*

* In connection with the relief of excessive blood-pressure, which arises from the widening of the peripheral arteries, it is I think clinically interesting to find, that when cerebral hæmorrhage, producing hemiplegia, takes place in a subject presenting a high maximum pulse-pressure, the radial artery on the paralysed side becomes considerably increased in calibre, and the blood-pressure falls on both sides; so that it would seem that the hæmorrhage, inducing at once an enlargement of the calibre of the arteries over half the body, relieves the general blood-pressure, and thus limits the disposition to further extravasation. The following case is instructive from this point of view:—

1893.

Miss. B., æt. 64 ... *Radial calibres* S., R., and St., 2·0 mm.
Glycosuria ... *Obliterating pulse-pressure* ... 400 grammes.

1894.

Left hæmiplegia ... *Radial calibre* S., R., and St.
from cerebral hæmorrhage." *Right* 2·5 mm.
: March, 1894 ... *Left* 2·9 mm.
 Obliterating pulse-pressure 280 grammes.

The patient has been glycosuric with a high pulse-

CHAPTER V.

CONCLUSIONS: RESUMÉ OF OBSERVATIONS.

I WILL briefly recapitulate the leading conclusions which the observations I have made with my pulse instruments support.

1. The principal shortcomings of this pressure for several years. Last year the obliterating pressure exceeded 400 grammes, and the radial calibre (2.0 mm.) was uniform in all the postures, and was equal on the two sides. When attempts were made to relax the restricted diet, the glucose in the urine immediately increased. To her physician I expressed a fear that cerebral hæmorrhage might supervene. That event did occur last March, producing left hemiplegia. Her physician then remarked the fall of the pulse-pressure, and the reduction of the sugar in the urine to mere traces. The paralysis has now nearly passed away. The pulse-pressure is reduced on both sides to 280 grammes. The radial measurements have increased: the calibre on the right (unaffected) side being 0.5 mm., and on the left 0.9 mm. in excess of last year's observation.

(or indeed of any other) instrumental mode of observation of the pulse are :—

(a). The inapplicability of it to those cases in which structural irregularities of the radial artery and of the wrist are present. Observation is thereby excluded in a certain proportion of cases.

(b). Some degree of deftness in the observer is necessary for trustworthy reading of the instruments.

2. In health the calibre of the systemic arteries never remains persistently uniform, but is continually varying within pretty wide limits in reponse to change of physiological condition ; and the variations follow a definite order (pp. 12-30).

3. In disease, pronounced departures from the physiological order of variation are met with—as revealed by change of posture ; such as the following :—

(a). The measurement uniform in the postures.

(b). The maximum measurement in recumbency.

(c). The postural variation greatly restricted or amplified.

(d). The calibre—whether uniform or varying—much reduced or enlarged.

(e). The two radial calibres asymmetrical.

4. Postural uniformity may be temporary or persistent. When temporary, it may be due to goutiness, or to arterial constriction from some source of irritation; when persistent the cause may be arterio-fibrosis, myxœdema, syphilis, gout, or chronic interstitial nephritis (pp. 34-49).

So far my observations have shown, that the detection of a uniform radial calibre may prove to be of considerable practical value; for, though it may now and then merely indicate a transitory condition of little or no pathological significance, it will always keep the observer alive to the possible existence of one or other of the important diseases in which it has been found to be a common clinical feature.

5. The maximum measurement persistently present in the recumbent posture is, as a rule, clinically significant of an asthenic and impoverished state—especially of the nerve centres and the blood; or of the existence of some source of irritation; or of a combination of both these pathological conditions. When the predominant clinical feature present is asthenia, the radial calibre diminishes as much in the standing posture as it increases in the recumbent (pp. 32, 33).

6. Restricted variation indicates either an increase of arterial tension, or the existence of slight organic changes in the arterial wall (p. 40).

7. Amplified variation, as a rule, implies subnormal arterial tension (p. 40).

8. The radial calibre may be diminished in a marked degree from :—

(a). Vaso-motor constriction, the result of operative procedures, or of pain, or of some source of irritation—especially when located within the abdomen.

(b). Passive reduction, as in states of cachexia and wasting.

(c). Organic reduction, as in arterio-fibrosis, syphilis (secondary and tertiary stages), and chronic gout (p. 51).

9. The radial calibre may be enlarged as a result of increased peripheral resistance, or loss of elasticity of the arterial wall or reduction of arterial tonus (p. 52).

10. Asymmetry of the radial calibres, when showing a disparity of at least 0.5 mm., is of clinical significance, and may arise from :—

(a). Mechanical pressure.

(b). Vaso-motor constriction (distal irritation).

(c). Hemiplegia (p. 41).

It produces an inequality of the surface temperature of the two sides (pp. 48, 49).*

* Bilateral thermometric observation has afforded me some interesting clinical data—not merely in the febrile, but in the non-febrile. It is of course greatly facilitated by using, as I do, two thermometers known to register alike throughout the scale.

11. The chief clinical value of pulse-pressure readings rests with the detection of those which indicate an excess of the pressure normal to the individual. The slightest rise of the intra-arterial pressure above this point—which varies somewhat in different persons—abolishes the postural variations; so that the arteriometer becomes a useful corrective and supplement to the pulse-pressure gauge (p. 127).

12. The pulse-pressure gauge is useful in definitely determining the excessive degrees of pulse-pressure which are mischievous to the heart and the arteries; and in revealing with much more precision than can be acquired by the finger the less pronounced grades of it, which may perchance escape digital detection, and which may be advantageously met by timely treatment (pp. 129, 130).

13. When the radial blood-pressure is increased, the calibre may be diminished or enlarged; diminished by the predominance of vaso-motor constriction, and en-

larged when the distensive power of the increased intra-arterial pressure fails to be balanced by muscular contraction (pp. 53, 54).

14. Radial calibration may provide useful diagnostic hints in respect to gout, rheumatism, chronic rheumatoid arthritis, syphilis, myxœdema, chronic renal disease, arterio-fibrosis, angina pectoris, anæmia, and asthenia in its various forms (pp. 55-64).

15. Observation of the radial calibre and pulse-pressure are of practical utility in regard to treatment; in selecting and adjusting the remedial measures—such as tonics, evacuants, recumbent rest, exercise, massage and baths—and in observing the effects produced. The pulse instruments have specially demonstrated the great restorative value of such physiological agencies as recumbent rest, exercise, diet, massage, baths, and mineral waters (pp. 64, 132-148).

16. Radial calibration may suggest and aid enquiry. It has, for example, thrown some light on the unsettled questions relating to the effects of anæsthetics and of operative procedures on the circulation of man ; and it has opened up an interesting enquiry relating to the function of the supra-renal bodies (pp. 77).*

* The arteriometer may likewise contribute some evidence towards the solution of certain debated clinical questions, such as the relation which gout bears to eczema (or certain forms of eczema), asthma, &c. ; and it may prove useful in testing and demonstrating the efficacy or otherwise of new modes of treatment. So far my observations bearing on the connexion between gout and eczema suggest a definite ætiological relation in certain cases, while in others it is not apparent ; but this matter, all important in regard to treatment, demands more extended observation. Just as these pages are passing through the press, illustrations of the suggestive guidance of the arteriometer present themselves in several directions. For instance, observation is demonstrating the undoubted efficacy of the Harrogate massage-douche in the treatment of the reduced arteries of syphilis, and points to it as a valuable adjunct to the therapeutic measures hitherto employed in that disease ; and likewise in the treatment of gouty eczema.

ADDENDUM.

THE RESULTS OBTAINED BY THE ARTERIOMETER CONFIRMED BY EXPERIMENTS ON ANIMALS.

I HAVE shown (pp. 86-89) that the readings of the Arteriometer in regard to the constrictive effects of supra-renal extract on the arteries have been conclusively proved by experiments on animals ; and I have lately observed, that the result of intra-venous injection of thyroid extract is confirmatory of the indications furnished by the instrument. It has now, therefore, been demonstrated in the laboratory that the extracts of the supra-renal bodies and of the thyroid gland exert contrary effects on the arterial wall—the former contracting, and the latter dilating it ; the position which was in the first instance suggested by the Arteriometer (see p. 84).

Experimental evidence proving variations in the radial calibre and blood-pressure as the result of posture and of gravitation, by which I have attempted to test the vaso-motor mechanism in man, has not, however, been forthcoming; and up to the present I have been left to my own unsupported observations in the human subject.

All along, however, I have been persuaded, that the faithful record of fact without reference to theory or explanation would some time or other be confirmed by the results of experiments on animals. On the eve of publication that belief has, I am happy to say, been realized; and I now have the satisfaction of adducing experimental proof of that which is the key-stone of this enquiry.

Mr. Leonard Hill, Assistant Professor of Physiology, University College, London, has for some months past been investigating the effects of gravity on the circulation in dogs, cats, and monkeys; and the outcome of his important work provides the experimental counterpart of

the physiological portion of this volume—and of the pathological variations of the arterial calibre which are founded on it.

Through Mr. Hill's courtesy I have had the pleasure of going over all the tracings which will illustrate his forthcoming paper—a paper which will not only be a most valuable contribution to our knowledge of the forces concerned in the circulation, but will prove of much practical value.

Mr. Hill's work not being published I cannot of course quote particular experiments or portions which prove the physiological facts I have adduced; I am, however, greatly indebted to Mr. Hill for the following resumé of some of his positions bearing on my observations.

“At the time when I was just completing a paper on a long series of experiments on the effects of gravity on the circulation—a paper which will be shortly published—I was fortunate enough to find that Dr. Oliver had obtained independently, and by an absolutely different

method, many of the same results which I had obtained in monkeys. By means of the most ingenious instrument, the Arteriometer, Dr. Oliver has found, that in the normal man, the diameter of the radial artery is greater in the standing posture and less in the recumbent position. He has also observed, that the fall of the calibre in recumbency is often preceded by a temporary rise. In the abnormal man, in a state of asthenia or shock, Dr. Oliver has determined that the diameter is less in the standing posture and greater in recumbency; the arterial changes in the postures being entirely reversed.

“Now in normal monkeys I have found, that the blood pressure falls at first in the vertical feet-down position, owing to the hydrostatic effect; and then rises, owing to the over-compensation of the hydrostatic effect through vaso-constriction in the splanchnic area. If, on the other hand, the monkey be turned from the vertical feet-down posture to the horizontal position, the blood pressure at first rises, owing to the hydrostatic effect, and then

falls owing to over-compensation by vasodilatation and cardiac inhibition.

“In monkeys, however, weakened by long anæsthesia, or operative procedures, the conditions are reversed; the pressure falls in the feet-down posture, and rises in the horizontal position.

“There is, therefore, an exact agreement between the results of the Arteriometer and the physiological results obtained by me on monkeys.

“The accuracy of the arteriometer was shown to me in another and more striking way. Dr. Oliver informed me, that ether as an anæsthetic produced a different result to chloroform on the diameter of the radial artery. By my investigation on chloroform I have found, that this drug when pushed produced a rapid paralysis of the splanchnic vaso-motor mechanism, and in consequence a most marked fall of blood pressure in the feet-down position. On testing the effect of ether on a dog, Dr. Oliver's observations were at once established. Ether produced at first no fall of pressure when pushed with the animal

in the feet-down position, and the fall, when it did occur, was extremely slow and gradual.

“Dr. Oliver ascribes the diminution of the radial diameter to three causes:—1. Organic change—arterio-fibrosis. 2. Vaso-constriction. 3. Passive shrinking.

“It is in regard to changes produced by passive shrinking that my results will be found to agree exactly with those obtained by Dr. Oliver on man. From my investigations I have found, that the influence of position on the circulation affords us a most delicate test of the condition of the vaso-motor mechanism; and I believe that the Arteriometer will be an instrument of great clinical value, as it will enable us to apply this test to man.”

According to the teaching of these experiments, when the maximum radial calibre is found in recumbency, and the minimum in the active postures—as during digestion (see p. 19), in the second stage of exercise (see pp. 15, 16), and in asthenia and loss of tone—the diminution in the sitting and standing positions is

due to reduction of the radial fulness, in consequence of the transference of blood through the agency of gravity into the legs and the splanchnic area; and the radial enlargement in recumbency arises from the return of the blood from these regions—it being no longer retained there by gravity.

It would, therefore, seem that gravitation—which comes prominently into play in the conditions just specified—should be accepted as an important modifier of the distribution of the blood, which has not hitherto been sufficiently recognized by physiologists.

Inasmuch as the reduced tonus of the vessels in the areas into which the blood gravitates is the disposing cause of this transference, this event should be much less liable to occur, were it possible to bring vaso-constriction into play, and thus to tone the arterial walls. Experiments on animals have shown that the supra-renal extract exerts a powerful influence in this direction; and, on prescribing it in asthenia, I have frequently

remarked how quickly the postural calibration has been restored—the maximum measurement becoming apparent in the active postures, and the minimum in recumbency. This fact I have frequently observed.* On the other hand, the re-

* The experimental and clinical evidence shows that supra-renal extract is a powerful cardio-vascular stimulant or tonic. The intra-venous injection of it in animals produces very pronounced cardiac inhibition; but notwithstanding this, the energetic contraction of the arteries and arterioles which it causes, suffices even to raise the intra-arterial blood-pressure. When the vagi are cut the ventricle contracts with great force and frequency, and the blood-pressure rises to an enormous extent. From the dose (m̄xv. ter die) I have merely observed the tonic effects on the vascular system, and I have not met with slowing of the heart from inhibition; perhaps that result can only be induced by comparatively large doses. It is, I think, probable that much larger doses may be safely administered than I have hitherto employed; for the experiments on cats and dogs have shown that large quantities of the extract—decidedly large in proportion to the weight of the animal—may be injected into a vein to produce a temporary but very pronounced effect, or may be allowed to gravitate into it so as to maintain a continuous and profound action, without destroying life. Much experimental and clinical observation is of course required, in order to settle the necessary details bearing on the therapeutic use of the remedy.

laxant effects of thyroid extract on the arterial wall should favour the occurrence of the asthenic form of radial calibration in the postures; and my observation of the radial calibre in thyroidism confirms this anticipation.

My clinical experience of the supra-renal and thyroid extracts, therefore, accord with the results obtained in the laboratory; but I had no satisfactory explanation of it to offer, until I observed Mr. Hill's interesting experiments and studied his tracings.



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